AGRICULTURAL ENGINEERING

Published monthly by the American Society of Agricultural Engineers

Publication Office, Bridgman, Michigan

Editorial and Advertising Departments at Society headquarters, St. Joseph, Michigan

Subscription price to non-members of the Society, $3.00 a year, 30 cents a copy; to members of the Society, $2.00 a year, 20 cents a copy. Postage to countries outside the United States and possessions, $1.00 additional. Application for entry as second-class matter at the post office at Bridgman, Michigan, pending. The title "Agricultural Engineering" is registered in the U. S. Patent Office.

F. A. WIRT, President **RAYMOND OLNEY, Secretary-Treasurer**

Vol. 6 SEPTEMBER, 1925 No. 9

CONTENTS

American Society of Agricultural Engineers

THE American Society of Agricultural Engineers is the national organization representing the agricultural-engineering profession. It is the principal source of and clearing house for technical information and data in its field. Its function is to provide a central point of contact for agricultural engineers—to coordinate their efforts in developing the science and art of engineering as applied to agriculture. Its principal objective is to formulate a distinctly agricultural-engineering science, based on engineering technique and specific agricultural requirements, to serve as a foundation for the profession.

Agriculture, the oldest and most fundamental of all industries, is the last to be engineered. Progress in this direction is still far behind that attained in transportation and manufacturing. But the agricultural engineer, visualizing the future and fighting his way through precedents and orthodoxies, is making real progress in putting agriculture on a sound engineering—and consequently economical and efficient—basis. He foresees not only the necessity for, but the realization of a development of agriculture along engineering lines as far-reaching as that already attained in the manufacturing industries and transportation.

The difficulties which now and have heretofore beset agriculture are due largely to a lack of proper engineering. It is the agricultural engineer's duty then to keep the development of engineering science abreast of the requirements of a rapidly developing agriculture.

The engineering requirements of agriculture are, to a large extent, quite unlike those in any other field. The need for the development of new principles and data to meet these requirements is particularly apparent. The projects for investigation and study that might be undertaken by agricultural engineers are legion, many of which call for the most fundamental research. Outstanding progress has been made in this direction and real achievements have been recorded, but the field is yet new and the surface has scarcely been scratched.

This emphasizes the desirability—if progress is to keep pace with the need—of the closest possible cooperation and understanding between individuals and groups interested in promoting all phases of agricultural engineering. Obviously the most effective and most logical agency for fostering this cooperation and understanding and for coordinating individual and group efforts is the national organization representing this field—the American Society of Agricultural Engineers.

AGRICULTURAL ENGINEERING

The Journal of Engineering as Applied to Agriculture

RAYMOND OLNEY, Editor

Vol. 6 SEPTEMBER, 1925 No. 9

EDITORIALS

A Work Shop On Every Farm

ONE of the big opportunities for agricultural engineers lies in the education of the farmer in the more efficient repair of his machinery and equipment. In times of agricultural depression, it is necessary for the farmer to economize if he is to make farming a paying business. He must stop all leaks of profits, small and large. He must use labor-saving machinery and equipment. He must keep his machinery in good repair and avoid serious breakdowns and delays in the midst of a busy season. Efficient and timely repairs make for long, satisfactory, and uninterrupted service.

A few years ago it was possible for the farmer to get efficient repair work done by the village blacksmith at a reasonable cost. But today many of these competent repairmen have turned their shops into garages and are now in the more lucrative business of repairing automobiles. Moreover, a farmer equipped to repair his own machinery will keep it in much better shape than his neighbor who has to drive to town for every little repair job. It is, therefore, desirable and, in many cases, necessary for the farmer to do more of his own repair work than formerly. He does not need to be an expert at blacksmithing, welding, and the higher arts of repair work, nor does he need an expensive outlay of tools to do his own repair work. The farmer with a reasonable amount of good common sense and a few well-selected tools can do most of the necessary repair work on the average farm, and save himself money that would have been spent for repairs and for replacement of machines prematurely discarded. Most important of all, he can often save valuable time in the midst of a busy harvest season.

The ideal should be a well-selected set of tools—not necessarily an expensive or an extensive set—in some kind of a shop, on every farm, and a farmer reasonably skillful in their care and use. The departments of vocational agriculture in the rural high schools, the agricultural colleges, the farm press, and many other agencies are doing splendid work in educating the farmer in farm shop work and in encouraging efficient repairs on the farm. All of us, as agricultural engineers, should pass up no opportunity to lend a hand to this sort of program.

M. M. JONES

Fire Protection and Prevention

Editor, AGRICULTURAL ENGINEERING:

I NOTICE in the August issue of AGRICULTURAL ENGINEERING an editorial, entitled "Fire Protection and Prevention," by E. Grant Lantz. It might be interesting to agricultural engineers to know what we are doing in Talbot County, Maryland, along that line.

Our county is purely a rural one. The county seat, Easton, is a town of 3500. One motor fire engine (combination chemical hose and pump wagon) is kept there, but due to insurance regulations it is not permitted to leave the town limits. Another smaller engine is kept in another town. Aside from that the county had no fire protection.

A number of the rural residents decided that a county fire engine was an absolute necessity; accordingly, a committee was organized and a drive for funds started. I was the secretary of that committee and worked very hard to put the thing over. We raised about $4000 by voluntary contributions, the county commissioners added $500, and the town of Easton another $500. A Graham-Dodge speed truck was purchased and equipped with a chemical tank, fire pump and a thousand feet of hose. This engine was placed in charge of the Easton volunteer fire department, the title being held by the town of Easton. Maintenance is paid half by the town of Easton and half by the county commissioners. The engine gives service anywhere in the county, the farthest point being about thirty miles from Easton. There are a great many bodies of water throughout the county so that we can put a stream on a fire in about 50 per cent of the cases.

As a further auxiliary the volunteer firemen collected a considerable sum of money to equip another chemical engine for county use. I secured the gift of a second-hand Packard automobile which was quickly converted.

The firemen are exceedingly enthusiastic and active in responding to all county fires and have saved a tremendous lot of property in the rural districts. Incidentally, the work of the Easton firemen has brought about a much better feeling between farmers and town folks, where, unfortunately, there is apt to be friction.

By using the two pieces of chemical apparatus we can do very good work wherever there is no water. Extra changes are carried on the engine and when one chemical tank is exhausted it is immediately refilled even at the fire.

The expense of this fire protection is ridiculously small since practically all the overhead charges are covered by the regular appropriation of the town of Easton for maintaining its own fire department.

I believe that a very great many small towns could maintain two engines like this at practically no more expense than one engine after the first cost of the duplicate outfit was met. The second engine reduces the insurance rate in the town quite materially. The most serious matter is that absolutely no credit in rural districts is given by insurance companies for this sort of fire protection although it reduces the fire loss tremendously. Nor is any reduction in rural insurance rates given for fireproof buildings. My own country home recently constructed has all first floors of reinforced concrete surfaced with tile; there is no wood whatever. My chimneys are properly constructed and lined with terra cotta. I also have fire extinguishers and fire hose properly located in the house. Nevertheless I do not get a cent of credit for these things.

It seems to me that the American Society of Agricultural Engineers might have properly appointed a special committee to investigate this whole matter and make a report. I happen to know that something is being done along the line of rural fire protection in one or more of the New England states; just how this will work I cannot say. But I would be very glad to have a committee investigate it and also investigate what we are doing.

WILLIAM DRAPER BRINCKLOE

Getting Recognition

WHETHER he will admit it or not, every professional man craves recognition for his work and accomplishments. Such recognition is perhaps attained oftener through his activities in the technical organization which represents his profession than in any other manner. For example, the men recognized as the leading engineers in any branch of the profession are usually those who have been most active in the society which represents their particular field. This is especially true in the case of the American Society of Agricultural Engineers, which organization encourages its members to take an active part in society affairs. Those who wish to volunteer for specific lines of Society work are urged to communicate with the Secretary.

The Power Take-Off for Tractors*

By F. N. G. Kranich

Mem. A.S.A.E. Manager, Tractor and Implement Bearings Department, Timken Roller Bearing Company

BY THE term "power take-off" we refer to the mechanical means whereby power in the form of rotary motion is transmitted from a tractor engine to a machine unit which may be attached directly to the tractor or coupled to the drawbar and pulled behind it.

In a very broad and literal sense the belt pulley is a power take-off, but is excluded from the general understanding of the term because a pulley employs transmission by belt to drive a stationary machine. In a similarly comprehensive sense the drawbar might be construed as a power take-off because it is the means whereby tractor power is applied to the drawn unit.

There are, however, certain examples of what might be termed power take-offs other than the belt pulley and the drawbar which are not embraced within our present understanding of the term, and which are of some slight interest from a historical standpoint. On the Pacific coast, in about 1904 or 1905, a combined harvester-thresher was used in connection with steam tractors. A steam engine was mounted on the harvester, just as internal-combustion engines are used nowadays, but this harvester engine was operated by steam brought from the tractor boiler through a hose. In a broad sense this constituted a power take-off.

In early times, that is, early in the history of power farming, the steam plowing outfits used to break the virgin prairies of the Northwest often were provided with a steam-driven plow lifting device, the steam being derived from the traction engine boiler, again being a sort of power take-off. Another example is found in the steam engines employed some years ago for hauling in mines, gravel pits, timber districts, etc. These frequently were equipped with winches carrying drag lines. When conditions rendered it impracticable to draw the load directly behind the tractor, the latter would be run ahead some distance, perhaps a few hundred feet, with the winch line attached to the drawn unit being paid out as the tractor advanced. Then the tractor wheels would be blocked and the winch operated to bring the load up to the tractor, when the process might be repeated if it seemed desirable, or a direct drawbar hitch made. Commonly these winches were driven from the belt pulley, or at least from the crankshaft of the engine, sometimes by belts and sometimes by chains. Bevel gears also were employed. Closely related to the foregoing are cable plowing outfits.

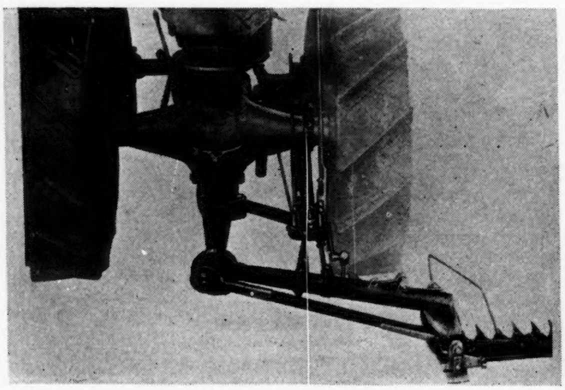
Somewhat different, but getting closer to the present form and application of the power take-off, was the use, by a certain manufacturer about 1909 or 1910, of a stationary gas engine for driving the mechanism of a grain binder. Instead of being mounted directly on the binder, as became rather a general practice later, the engine was mounted on a separate truck trailing behind. Power from the engine was transmitted to the binder by means of a chain. The binder, of course, together with its trailer was horse drawn in those days.

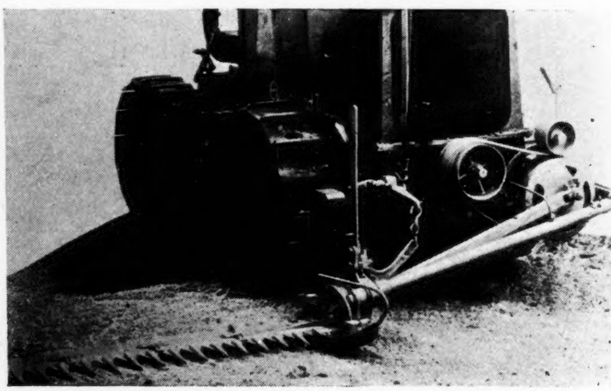
Most of the farm implements and machines now in standard use were developed for use with animal units as the source of power. Inasmuch as animals are capable of delivering power only on the drawbar, so to speak, it was natural and necessary that whenever an implement or machine required rotary motion, it was secured by means of a bullwheel running on the ground and transmitting its motion to the working parts through gears, chains, etc. The application of bullwheel drives was not limited entirely to planting and harvesting machinery of moderate size but has been employed on combined harvester-threshers, in which case the power requirements involved not only a 12 or 16-foot cutting mechanism, but also a complete threshing machine. As might be expected, the attempt to pick up so large an amount of power by the contact between bullwheel and soil proved very inefficient, and in consequence this method of driving harvester-threshers has been practically abandoned.

In the bullwheel method of drive the speed of the rotating parts is proportional to the rate of travel of the machine, if we assume that there is no slippage between the bullwheel and the soil. Whether this relation, the speed of rotating parts being a function of forward travel, is most desirable is a debatable point. But the assumption of zero slippage between bullwheel and soil is not borne out in practice and introduces difficulties, often serious and sometimes insuperable. When we consider that the operation of belts on pulleys, steel wheels on steel rails and rubber tires on concrete roads involve small percentages of slip, it is easy to understand that with soil, which is never a true solid but always more or less plastic, and sometimes approaching the nature and consistency of cup grease, slippage becomes a material factor, particularly when the amount of power to be picked up by the bullwheel is considerable. It is no uncommon thing for slippage to reach 12, 15, or 20 per cent. Speaking more particularly of the grain binder and the conditions it encounters in the rice country, or during rainy seasons, it is no uncommon thing for the machine to clog and the slippage to reach 100 per cent.

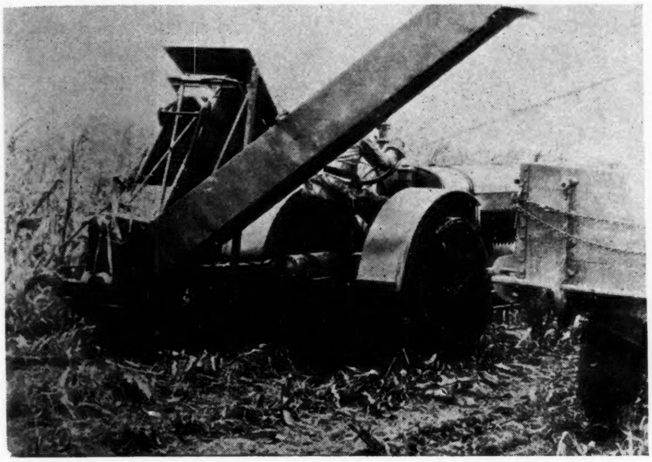
The exacting burden put upon the bullwheel by the grain binder together with the urgent necessity for harvesting rice

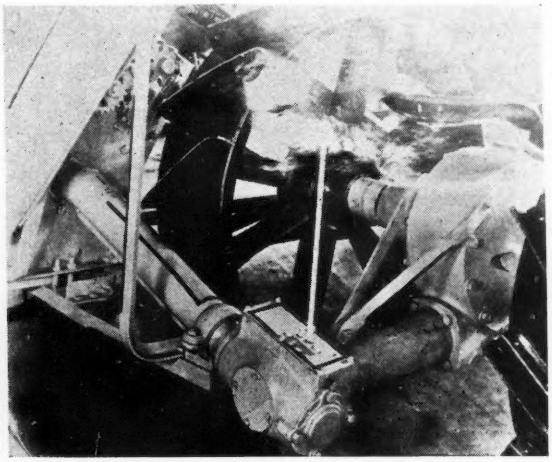
*Paper presented at a meeting of the Farm Power and Machinery Division of the American Society of Agricultural Engineers, Chicago, April 29, 1925.





Mowing attachments for tractors driven by power take-off. (Left) Sickle bar operated from the worm of the final drive of the tractor. (Right) Cutter bar mechanism driven by a belt from a pulley on the front end of the crankshaft.





General view (left) and close-up view (right) of a power take-off attachment used in connection with a corn picker

or grain at the correct time regardless of weather and soil conditions, created a demand for a power unit, separate from the animal units used for drawing the machine, which would drive the working parts independently of the bullwheel. Responding to this demand it became rather common practice to install one or two-cylinder internal-combustion engines of 3 to 10 horsepower on grain binders. Several manufacturers developed special binder engine outfits, including in addition to the engine suitable means for mounting, for transmitting the engine power to the binder mechanism, and for adapting the engine itself to the operating conditions. Leaving out of account those territories where traction conditions are always poor, it might be said that the demand for and distribution of these binder engines was spasmodic, few being sold except where the caprices of weather made the grain ripen on a soft and slippery soil, and then dealers and manufacturers were overwhelmed with orders for immediate delivery and installation.

These binder engines commonly were governed at a constant number of revolutions per minute, consequently they drove the binder mechanism at a constant speed regardless of the rate of travel, or even whether the machine was traveling at all. They were so geared to the working mechanism as to give the latter just a trifle more speed than was expected to be necessary at the fastest rate of travel likely to be employed. It is worth mentioning that this rate of travel was not necessarily limited to the gait of horses, because these binder engines have been and are used in connection with tractor-drawn binders. It may be pointed out that in such cases the elimination of the bull-wheel drive on the binder not only eliminates difficulty and limitations at that point, but by doing away with the tractive resistance due to the bullwheel, reduces by just that much the drawbar power required to pull the outfit and thereby simplifies the traction problem under the tractor drivewheels.

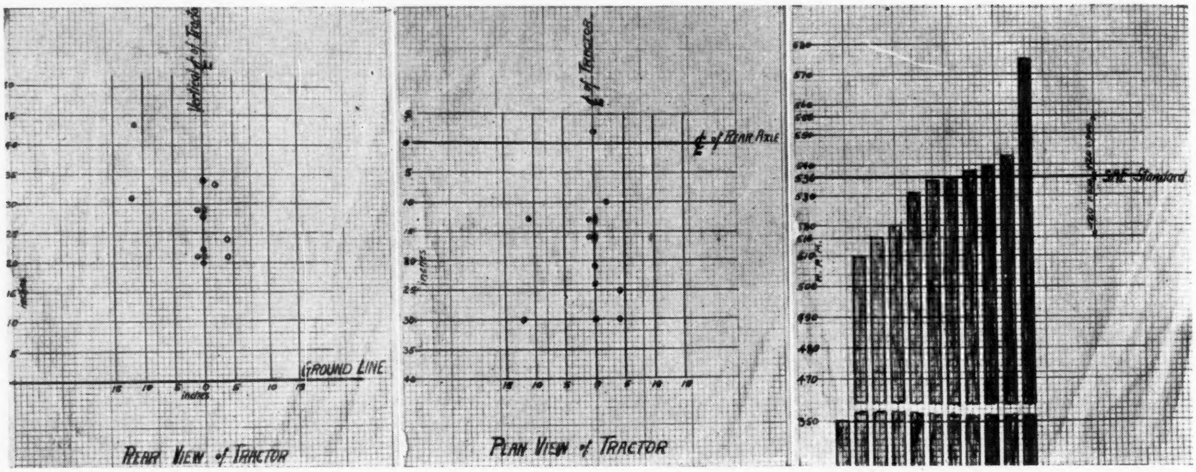
The binder engine in the same size and form has been applied to a few other farm field machines, notably the potato digger. The modern prevailing practice of supplying harvester-threshers with their own built-in engines is in principle only the further application of the binder engine idea. But whereas the binder engine always was sold as special equipment to meet a special condition, the harvester-thresher was about the first, if not the very first, agricultural machine carrying its own engine as regular equipment. In these machines the power units sometimes are as large as 40 or 50 horsepower.

Power take-offs as at present built may be divided into two classes according as the speed imparted to the driven machine is a function of engine speed or a function of the rate of travel. The distinction between the two is shown nicely in two of the illustrations portraying mowing attachments for tractors. In one case the cutter bar mechanism is driven by a belt from a pulley on the front end of the crankshaft. It has, therefore, a constant speed regardless of the rate of travel, or is directly a function of the engine speed. The other attachment has the sickle bar operated from the worm of the final drive of the tractor. In this case the speed of the cutting mechanism is proportional to the rate of rotation of the drivewheel or, except for the error due to slippage, is a function of the rate of travel.

These two illustrations will serve also as a basis for a somewhat different two-fold classification, according as whether the power imparted to the driven machine or attachment is taken through the same clutch as the traction gearing of the tractor, or is independent thereof. It will be observed that the mowing attachment driven by belt from the pulley on the front end of the crankshaft will continue in operation even though the transmission clutch of the tractor be disengaged and the outfit stationary, whereas in the other outfit the cutter bar cannot be put in operation except as the tractor moves forward.

As to whether the speed of the power take-off shaft, and consequently of the machine which it drives, should be a function of engine speed or of rate of travel there is difference of opinion among agricultural engineers, and it is likely that this difference of opinion will continue since there are some applications for which the former seems preferable, while in other cases the latter seems superior. The advantages of constant relation to engine speed are well illustrated in the conditions often encountered in the rice country where the stand of grain is heavy and the traction is poor. Under such circumstances the tractor may be put in low gear, giving it the necessary advantage in meeting adverse conditions of drawbar efficiency and reducing the rate at which the heavy grain comes to the binder. At the same time the binder is kept operating at full speed, enabling it to do its work without the crowding, delay and possible breakage which would occur if the rotating speed of the working parts were reduced in relation to the rate of travel. Machines for digging potatoes and for harvesting grain, whether it be small grain or corn, do a good deal better work when operated at a uniform speed. At the same time, soil conditions or steep grades may impose such a load on the tractor as to render expedient the use of a lower ratio of the tractor transmission. Or again, as in the case of rice, it may be desired to reduce the rate of travel to prevent overloading and clogging of the harvesting mechanism. Lodged and tangled grain, as well as exceptionally heavy or green grain, make such an arrangement desirable.

At the same time, in calculating the proper speed for a power take-off it must be borne in mind that the speed should be sufficiently high to permit ordinary operation in high gear without the harvester or other driven machine lagging behind the tractor, that is, lagging in its ability to take care of the material at the rate at which the tractor travels in high gear. Such a condition would be equivalent to what is encountered with bull gear drive when the bullwheel slips on the ground. The material entering the cutting, elevating, binding, or other mechanism in excess of its capacity causes clogging, imperfect operation, and often breakage. The rule among agricul-



(Left) This chart shows the location points of power take-off attachments as viewed from the rear of the tractor. (Center) This chart shows the location points locking down on the tractor from above. (Right) This chart shows the speeds of the power take-off shaft on the devices under consideration

tural engineers, therefore, should be to provide a slight excess of speed so that there will be a margin of safety.

Most tractors have governors; in fact, all tractors should have, and this constant governed speed in relation to the rate of travel in high gear constitutes the proper basis of calculation. It might seem unnecessary to emphasize this point, but some good power take-off attachments seem to have been unsuccessful because this point was overlooked.

The mechanical features of design and construction, and also the location of the final drive shaft of the various power take-offs which have been built vary as widely as do the kinds of tractors. It may be said that some of the power take-offs are merely temporary expedients to bridge a gap for the time being. Some have their form and location as an incident to the design of the tractor on which they are used and just happen to come in a certain place and operate at a certain speed. In the case of a manufacturer building two or three machines with power take-offs, the location and speed of this shaft is not the same on any two of them. This arises from differences in the size of the units and in the height and width of the tractor.

Some of these attachments are driven by belt from the tractor pulley. Some are driven by chains from the pulley shaft. Some are driven from the transmission gears on top of the tractor and some from the transmission gears on the bottom; some even on the right or left side, wherever the engineer found it convenient to attach with the least difficulty and expense. This results in a similar variation in the point at the rear of the tractor where the power take-off shaft is located.

Similar lack of uniformity prevails with respect to the amount of power which the power take-off is designed to transmit. In those which have been built the amount ranges from 25 to 100 per cent of the engine power. Obviously some understanding should be reached on this point, in order that the agricultural engineer may know the torque which the attachment will be called on to transmit and calculate his sizes accordingly.

One view of the matter is that the power take-off should not be capable of drawing off so much of the engine power that the remainder will be insufficient for propelling the tractor and drawing the machine behind it, as this obviously would incapacitate the outfit for the job intended and handicap the whole scheme of things. Many engineers conclude, possibly rather arbitrarily, that 50 per cent of the engine power available at the power take-off is enough.

On the other hand, there may be times when the tractor is standing still and none of the engine power is being consumed for traction purposes. The entire engine power is therefore available for use of the power take-off, if needed to clear out a clogged machine, for example. In such a case it is conceivable that the load might be heavy enough to impose a torque on the power take-off limited only by the capacity of the engine. Yet it is a question whether the transmission of so much power is really necessary, and whether the power take-off should be designed with this in view or whether the maximum torque to be transmitted should be limited to a lower figure by means of a slip joint or other safety device.

As a matter of good practice, slip clutches and other safety devices of various sorts have been embodied in power take-off drive shafts between the tractor and the drawn machine. These safety devices are provided with means of adjustment whereby the maximum torque may be changed to suit the power required by the machine being driven. They are not, however, calibrated or marked in any way so that the farmer can know the amount of power for which he is adjusting. The need for such calibration is apparent. On the other hand, there is some question as to whether the slip or safety device should be made adjustable and embodied in the power take-off, or whether it should be a part of the driven machine, designed and adjusted to suit the requirements of that machine alone. If the safety device is to be a part of the power take-off, as might seem logical in order that a single such device might serve for all the driven machines, the question arises as to the maximum and minimum torque for which it should be adjustable, or whether in fact it needs to be adjustable at all, since it might be possible to establish a standard figure adaptable to all the drawn machines.

Power take-offs for trailing machines invariably include a telescoping joint on the shaft to compensate for the varying distances between the tractor and machine as the outfit is turned and passes over uneven ground. Different machines may also call for varying distances or shaft lengths.

Power take-off attachments sometimes interfere rather seriously with the turning of the tractor. Many tractors are capable of turning very short, some at right angles, and some even are provided with means of turning on their own centers. To meet practical requirements the power take-off should permit turning at least as short as a square corner such as is commonly used in harvesting grain, corn, and hay.

Just as the power take-off may interfere with turning, it is conversely true that turning may seriously handicap the operation of the power take-off. Universal joints have their limitations. One of them is that as the angle of shaft through the joint increases the rotational velocity of the driven shaft is subject to increasingly greater fluctuation, with corresponding fluctuation in torque available and stresses involved. Within certain limitations it is possible sometimes to arrange universal joints in pairs so that these effects are neutralized, but the use of a number of universal joints is not a condition to be desired. However, power take-off attachments, which provide for short turning and overcome the natural defects of the universal joint have been designed and are on the market. These attachments permit turning square corners and maintain almost a constant speed for the driven mecha-

nism. In fact, there are some which provide a constant speed regardless of the angle at which the drawn machine may be.

When the power take-off driveshaft is located to the right or the left of the center line of the tractor it is obvious that the problem of making turns is complicated. There are some with which a turn to the left is not advisable, also some for which turning to the right is similarly inexpedient.

Among the accompanying illustrations are two charts in which have been plotted the points of attachment at the rear of the tractor of the power take-off attachments upon which this study is based. One shows the location points as they would appear in viewing the tractor from the rear, showing the height above the ground level and the distance to the right or left of the vertical center line of the tractor or, as happens in a few cases, directly thereon. The other shows the location of these same points as a plan view, that is looking down on the tractor from above. In this chart the attachment points are shown in relation to the horizontal center line of the tractor and the center line of the rear axle. To represent completely all the conditions involved this plan view should also show the center lines of the tractor drawbars, but this would have made the diagram unduly complicated. As a matter of fact, even the drawbar points would not have told the whole story, as the position of the rear wheel and the fender also have to be taken into account.

A third chart shows the speeds of the power take-off shaft on the devices under consideration. It needs no explanation with the possible exception of the three lines indicating the S.A.E. standard. This calls for a speed of 536 revolutions per minute with a permissible leeway of 20 revolutions per minute either higher or lower.

All these things call for agreement or standardization in some orderly plan because the manufacturers building drawn units are seriously handicapped in attempting to design machines to be driven through a power take-off. In recent conversation with a manufacturer he told me that he was ready to adapt his line to power take-off attachments for use with tractors, but that owing to the chaos existing in the tractor industry with respect to these points he is unable to proceed. He can develop parts to go with some one particular make of tractor but he does not want to be thus restricted. Nor is it necessary for him to do so because it would seem logical and easy for agricultural engineers to come to an agreement and to make definite decisions regarding these things.

Nor does the difficulty end with the manufacturer of driven machines. These various units may be sold with any tractor, or may be sold to a farmer already having any of the tractors involved. The same farmer may have one make of tractor and three, four or five of the various driven machines which should be supplied with power through a power take-off. The attachment is designed to simplify his problem and make his work easier and more efficient and yet, due to the conditions described above, the exact opposite may be the result. Under such circumstances the difficulties connected with the power take-off might outweigh its advantages and actually defer the common adoption and use of this fundamentally important method of utilizing tractor power.

It is particularly important that the power take-off be brought into general use as rapidly as possible because it is outstandingly a means of more certain, more rapid and more efficient harvesting. After all the work of plowing, disking, harrowing, smoothing, planting and perhaps cultivating the crops, after the rental value of the land has been invested, everything is at stake until the harvest is safely accomplished, and this is a job with exacting requirements as to timeliness. It must be done effectively and promptly if the farmer is to cash in on all his work and investment. By making operations almost completely independent of soil conditions the power take-off may be regarded as a valuable form of crop insurance.

Among the machines logically adapted to operation by the power take-off from the tractor are the grain binder, rice binder, hemp harvester, corn binder, grain shocker, corn picker, field silage harvester, potato digger, mower, combined harvester-thresher, orchard and field spraying machines, and other machinery of the same general power requirements.

In talking with agricultural engineers having to do with the design of grain drills, on which it might seem logical to use the power take-off, it appears the grain drill has not even afforded a field for investigation. The same situation prevails with manure spreaders, which are driven by power picked up from the ground by bullwheels. It appears that some experimental work has been done in this direction, but as yet nothing has been worked out to the point of promising tangible results. It seems likely that ultimately all such units as spreaders, drills, etc., will be operated from a power take-off. It might be mentioned in passing that rotary plows of various types and sizes have been developed in which the power for operating the rotating tilling parts is supplied from a power take-off.

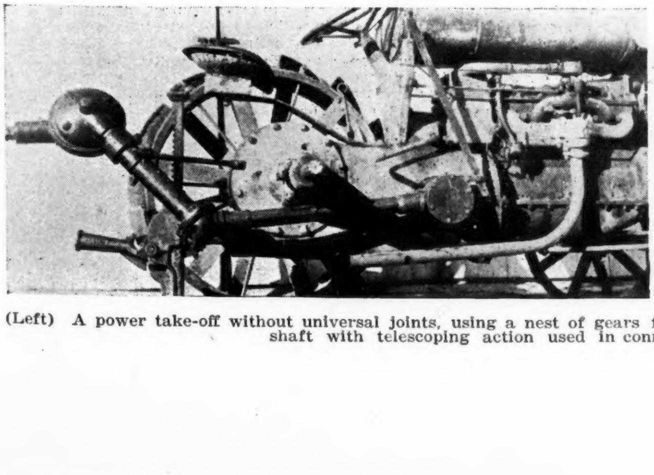
Another point of considerable importance from the practical operating standpoint, and one which will have influence with the farmer in making up his mind whether or not he wants to be bothered with a power take-off, is the ease with which the attachment is coupled and uncoupled with respect to the driven machine. It must be very simple and easy to do if the power take-off is to come into general use.

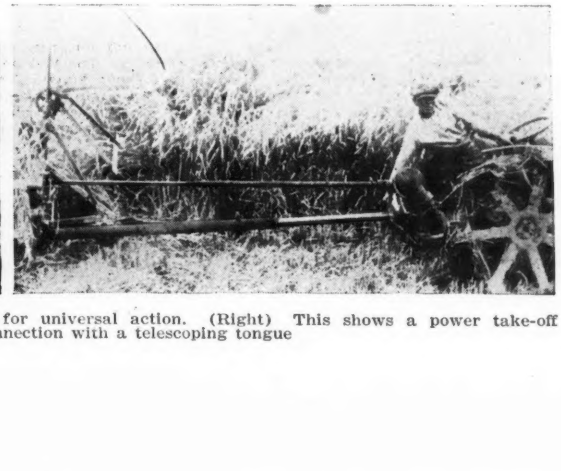
It should not be necessary to mention safety as an essential feature in the design of any power take-off. Constant proximity to the operator, the contributing hazard of the moving machine immediately behind, and the remoteness of the operator from fellow workmen or other assistance emphasize the need for keeping the mechanism enclosed or at least free from set screws or other projecting parts capable of catching the operator's clothing or otherwise exposing him to injury.

In conclusion the points which call for agreement by the engineers of the industry may be summarized as follows:

1. **Speed.** Whether it will be possible to select a standard speed suitable for all machines to be driven through a power take-off is problematical. There has already been adopted a standard speed for power take-offs, but some manufacturers are finding it difficult to use this speed without employing a gear box to raise or lower the speed to meet the requirements of the machine being supplied with power.

2. **Attachment to Tractor.** The means of attaching the power take-off attachment to the tractor is not the same with all makes of this device. It looks as if it might devolve upon the manufacturer of the driven machine to supply his own power take-off attachment. It would seem that the tractor





(Left) A power take-off without universal joints, using a nest of gears for universal action. (Right) This shows a power take-off shaft with telescoping action used in connection with a telescoping tongue

manufacturer should have a standard shaft on the tractor so that this part would be the same for all makes of tractors. It should be easy to put on and take off, regardless of whether it is a screw, spline, or any other means of coupling the shafts.

3. **Height.** As shown by the plotted heights, the distance of the power take-off shaft on the tractor above the ground is subject to rather a wide variation. It would appear that simplicity and good mechanical practice demand that the exact height should be determined by the structural details of the tractor. It is quite likely that considerable leeway in height might be allowed without interfering with interchangeability or with satisfactory operation of the device. Consequently, it is questionable whether this height should be fixed by any standard.

4. **Fore-and-Aft Location.** The distance between the driven machine and the tractor vary not only with the nature of the former but the design of the latter. Telescoping joints or shafts of some sort are necessary in any case, consequently this does not seem to be a vital point. It is related to the next point.

5. **Location with Reference to Drawbar.** The question here is whether the point of attachment to the tractor should be located with reference to the king bolt of the tractor drawbar, or the extreme rear end of the tractor, either the diameter of the drivewheel or the wheel guard, since these latter are the points which limit clearance in making turns.

6. **Horizontal Location.** The principle involved here as to the most desirable and most practical location is whether it should be on the vertical center line of the tractor or whether it should be permitted to be at the right or left of this line, and in the latter case what is the maximum permissible distance off center.

7. **Slip Joints.** Here the question arises as to whether the slip joint or other safety device should be a part of the tractor or included as a part of the power take-off attachment. As a third possibility it might be a part of the driven machine. The percentage of engine power to be transmitted by this device also calls for consideration.

Since the power take-off is now in process of development it is the right time to bring all these points to the attention of manufacturers both of tractors and of driven implements. It seems likely that there can be evolved a standard design, or designs, that will be suitable and acceptable for all concerned. This can best be brought about by close cooperation among the various manufacturers and engineers involved, utilizing perhaps some engineering society as a clearing house both as a means of arriving as quickly as possible at a practical working basis and of setting up a standard which will accomplish the greatest good for the greatest number.

There is no question as to the practicability and economic value of the power take-off attachment. The facts in the case demand a speedy development and use. Eventually the thing must be done and done right. The best time for doing it is right now when standards may be set up without entailing sacrifice of tools and materials by anyone. This will not be accomplished spontaneously, but will take work. Some two or three men must take the responsibility for pushing this thing along, not with a view to dictating the details of the procedure, but to keep things moving, and coordinating all the considerations involved in order that we may arrive at a practical working basis as soon as possible. To the rapid working out of such a program we should all lend our hearty support.

Discussion

Mr. Scarrett: There isn't any doubt in my mind but that the power take-off is a coming accessory unit for tractors, but just how near we are to having it at the present time I don't know. The request for an implement of this kind comes to an engineering department through the sales department, and at the present time I personally think the demand is a whole lot more apparent than real.

I don't mean to belittle the fact that there is a demand for it, but I don't think it is as great a demand as we sometimes are now led to believe. But it should urge us on to a satisfactory solution of the problem.

Mr. Kranich has covered most of the essential points which we should become united on, both as regards the tractor manufacturers and their power take-off provision, and also the implement manufacturers. We built a power take-off last year that was about the sixth design we worked on, and we were not very well satisfied with it, but the fact that we were not satisfied with it and couldn't feel that way about it, was due to the fact that we could not get information to work with.

If this unit is going to be made useful, we will have to know what the implement manufacturers need in the way of power-take-off provisions. There are a good many different kinds of implements that are subject to mechanical drive, and they are about as different in their construction as it is possible to make them. They serve all different sorts of purposes, and naturally they are not alike, so the problem that confronts the engineer is simply this: He wants to know the desired speed and direction of rotation and the point at which the power has to be delivered. The tractor manufacturer's part of the problem should end when he has provided a suitable take-off which delivers the power up to a fixed point on his tractor, and the implement manufacturer's job should start from there.

I don't think you can divorce the problem of power take-off provision from the hitch requirements of the different kinds of implements that have to be drawn. In our analysis of the problem we now feel that the proper place to locate the power take-off shaft is on the vertical center line of the tractor. That is simply because in this country the common grain binder is intended for left-hand operation, but in European countries it is for right-hand operation. To take care of both types of binders satisfactorily, you cannot put the power take-off in one place for one machine and elsewhere for another. You would be moving it all over the tractor, and you cannot make that flexible provision in the mounting and driving of the power take-off. So we have got to choose a place that seems to satisfy both extremes best, and that is the center line of the tractor.

Another point that should be considered is how far back of the rear axle should the first universal joint be located. We believe it should be far enough back of the center line of the tractor so that you can get your machines into a right-angled position with respect to one another. That may mean that a drawbar extension would have to be furnished along with the power take-off in order that the first knuckle joint would be directly above the king bolt of the hitch, which seems to be logical, so that you would minimize the telescoping action of the driveshaft in either right or left-hand turning.

The third provision is with reference to the height of the power take-off shaft, and to me that appears to be the least important that I am mentioning, but it should be within some reasonable limits.

The fourth thing is that there should be some standardized shaft end so far as the power take-off unit is concerned. If it is going to be splined, let's fix the size and length of the spline, that everybody in the implement business can make their first knuckle joint of standard construction so that when they sell an implement it will fit any make of tractor.

Unless we get down to these fundamental requirements for a power take-off, we are not going to get anywhere. Mr. Kranich's letters from implement manufacturers seemed to indicate that they are putting the responsibility back on the tractor manufacturer. I don't quite take that view of it. I think the manufacturer of the tractor has to receive his information from the implement manufacturer, and the only way that we can accomplish anything is to get together.

Mr. McGrew: Our experience with the power take-off has been extended over a period of about five years. My first experience came in 1920 when we were starting to operate a rice ranch in Arkansas. When we began to cut the rice in the fall, the conditions there were such that we could not use a regular binder on account of the ground being so soft, so it was up to us either to devise some way of taking the power off the tractor or to lose part of the crop. We used binder engines and about everything else, but we didn't get very far with it. We could see it was up to us either to devise a power take-off or quit the rice business.

We made several power take-offs the first year, but none of them were successful; in 1921 we had the same luck. But in 1922 we developed a device for the Fordson tractor, which we used on the binder, and it worked successfully. We equipped three of our binders with the outfits on Fordson tractors.

But it is a matter that is very much in the experimental stage, and nobody seems to know just quite what they want, because there are so many different types of tractors that require a different type of hitch, and while we experimented only with the Fordson tractor, we have a hitch that works very well on that tractor. It comes out on the right-hand side at the belt level. You take off the belt pulley and run the shaft directly under the rear axle and on top of the drawbar and straight back to the pitman on the binder. It has worked very successfully for us. It will turn either way as short as the Fordson will turn. We have never experimented with any other type of tractor. This device fits most any binder, so that for the time being, until the binder manufacturers and the tractor manufacturers get something for us exclusively on their own machines, we will have to get along with this.

As far as the height from the ground which the shaft should run, we run ours fairly close to the ground. In the rice fields we have mud and levees to contend with, and everything else, and when a machine will work in the rice fields, we feel it will work almost any place else.

We feel the first principle of a take-off is simplicity, because the average farmer doesn't know any too much about machinery; he doesn't take any too good care of it, and the simpler the machine is or the less there is to it, we feel the more success one has with it.

Another thing is the weight. We are trying to get along with a light take-off, where there won't be too much weight. We cannot put too much weight on our ground.

Mr. Ray: I began experimenting with the power take-off in 1921. For some time before that I had observed the necessity for such a device. I first fitted up a knuckle joint, or hook joint, to the worm of the Fordson tractor and found that it was not ideal,

(Continued on page 216)

A Method of Analysis of Ventilation Test Data*

By M. A. R. Kelley

Mem. A.S.A.E. Agricultural Engineer, U. S. Department of Agriculture

THE ventilation test work of the A.S.A.E. Committee on Farm Building Ventilation was continued during the past winter. Your chairman, ** in cooperation with the department of rural engineering of Cornell University, conducted tests on six barns in New York state. The shortest test was of approximately one hundred hours' duration and the longest three times as long. A great variety of weather was experienced varying from 36 degrees below zero to about the same point above zero. Data on flue temperatures were secured this year. These data are now being compiled and summarized and we hope to make them available at an early date.

In the report of the committee of last year we pointed out the need of studying the influence of the several factors which affect the ventilation of farm buildings considered separately. That there is a need for such data will be obvious to the agricultural engineer, but the means for obtaining this information are not so apparent. In order to realize some of the difficulties encountered, one need but consider the many factors which may affect the ventilation of a building. These may be divided into three classes: Atmospheric, construction and the animal factors. The first may be subdivided into temperature, humidity, wind (both direction and magnitude), and barometric pressure. The more important subdivisions of the second class are size, height and adjustment of flue, and size and insulation of the structure. Division of the third class leads to a study of the heat, moisture and carbon dioxide production of the animal and to reaction of the animal to his environmental conditions. It is the multiplicity of these factors, which may vary separately or collectively, that makes it difficult for an investigator to analyze the data from tests made under the conditions which prevail. Unfortunately several of the factors cannot be controlled, especially the weather conditions, and one must accept them as they are met.

The usual method of measuring the relative importance of the several factors is to group and average those which are comparative, but this is often a tedious process. The investigator then assembles all the data and interprets the results in terms of his own experience and that of others. There is always a danger of wrong interpretation when conclusions are based on meager information. This is especially the case when such a method is used in the analysis of ventilation test data.

The writer, in his search for methods of interpretation of such data, found three articles[1], which suggested the possibility of using the coefficient of correlation in the analysis of ventilation test data.

This is not a bad method as it has been used for a number of years by statisticians. No attempt will be made to explain in detail the theory of correlation, as this may be obtained by consulting the various textbooks on the subject. The agricultural engineer may find the method employed by the writer and explained later of value in other ways. To point out the numerous applications of this theory to agricultural engineering problems is impossible in an article of this kind, but one or two illustrations of its application to our ventilation problems, may serve to increase the interest of the reader and induce him to study the use of the theory.

The following table illustrates the value of the results of the application of the method. The meaning of some of the symbols will be clearly shown later. The table shows the comparison of five different barns with respect to the influence of outside temperature on the stable temperature. To one familiar with the conditions obtaining in the barns tested and with this method of analysis this table has considerable meaning. It is of course subject to the influence of the many variable factors previously mentioned, and those must be known for proper interpretation.

COMPARISON OF OUTSIDE TEMPERATURE AND STABLE TEMPERATURE

	r	X_r	E_r
1.	0.786	1.64	0.035
2.	0.562	1.70	0.085
3.	0.956	2.60	0.009
4.	0.902	1.19	0.240
5.	0.693	1.81	0.040

The first column represents the coefficient of correlation, r; the second column, headed X_r (known as the regression coefficient), shows the variation of one factor with respect to the other. In this case the first figure, 1.64, represents the variation of the outside temperature, for every degree of variation in stable temperature under the average conditions experienced during this test. It will be noted that there is a variation in the figures for the different barns, and we thus have a means of comparing barn construction, flue adjustments, etc. The reader will find in this table other evidence of its value, after he has read the following description of the method by which the results were obtained. An article showing how this method was used in determining flue velocities that might be expected at various temperatures, will be published at a later date. Obviously the possibility of being able to estimate probable flue velocities has a very important bearing on the design of a ventilation system.

Coefficient of Correlation

If there are two series of associated variables, such as outside temperature and stable temperature, there is a tendency for the high values of the first to be associated with the high values of the second, the variables are said to be correlated, and the correlation is positive; while if the high values of one factor are associated with the low values of the other, and vice versa, the correlation is said to be negative, and the best method yet devised for measuring the amount of correlation is the so-called coefficient of correlation.

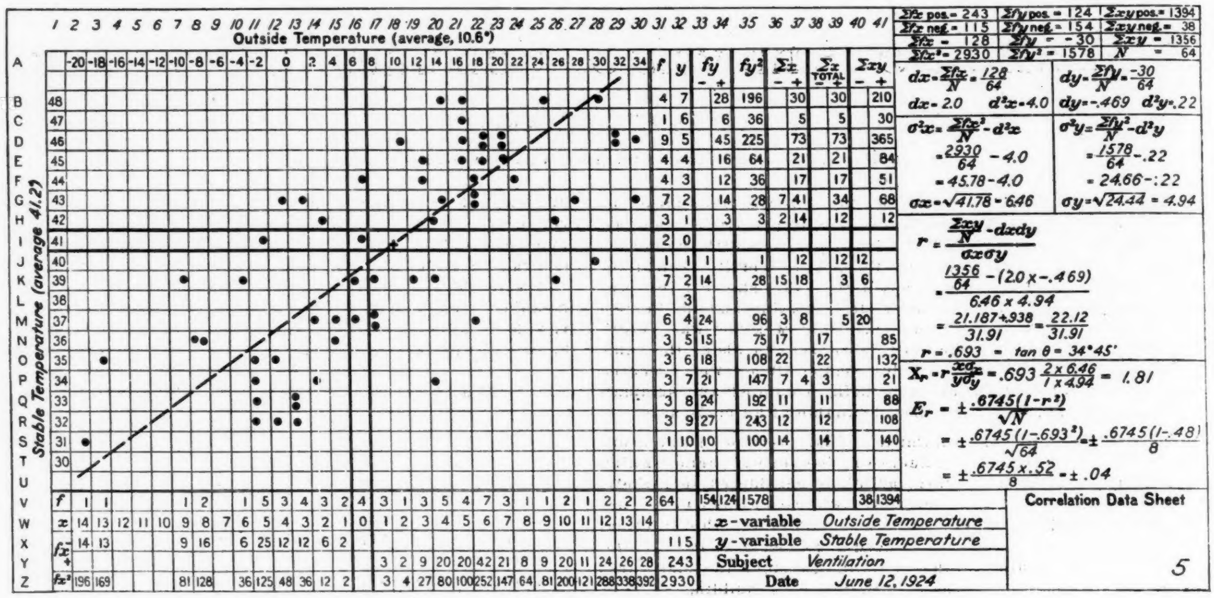
Expressed algebraically, r (the coefficient of correlation) $=\Sigma xy \div N\sigma_x\sigma_y$, where Σxy is the sum of the products of the x and y factors; N is the number of pairs of variables (the same as the number of records), sometimes called the frequencies; deviation x (σ_x) is the standard deviation of the first variable; and deviation y (σ_y) is the standard deviation of the second. The value of r will always be between plus one (+1) and minus one (−1). Plus one indicates positive correlation, minus one negative correlation, and to be significant, the value should be appreciably greater than the probable error (E_r). The larger the number of terms or number of records available, the greater the reliability of the results obtained from the application of the coefficient of correlation. The assumption is that there is less likelihood of a chance relation or exception to the general trend affecting the results, and its effect is minimized in proportion to the number of records.

It is generally known before the analysis is attempted which factor is causal (usually represented as the "x" factor) and which resultant (usually represented as the "y" factor), and consequently there should be little difficulty in interpreting the coefficient correctly. The coefficient of net correlation, affords a very good means of determining the net effect of each

*Paper presented at the eighteenth annual meeting of the American Society of Agricultural Engineers, Lincoln, Nebraska, June, 1924.

**Mr. Kelley, the author of this paper, is the chairman of the Committee on Farm Building Ventilation referred to.

[1]Correlation and causation, by Sewell Wright, Jr., Agri. Research, Vol. 20, January 3, 1921. Theory of correlation, as applied to farm survey data on fattening baby beef, by H. R. Tolley, U. S. Department of Agriculture, Department Bulletin 504. Method of testing farm-management and cost-of-production data for validity of conclusions, by H. R. Tolley, U. S. Department of Agriculture, Department Circular 307.



Data sheet for determining the coefficient of net correlation in ventilation test data

of several factors when it is desired to find the true relationship existing between the two. Although the correlation coefficient may not be a definite quantitative measure of the relationship of two factors, it is a relative measure of relationship existing between the factors being studied. If the relationship between factors is intimate, quantitative as well as qualitative results may be obtained. It therefore gives the investigator a single index which shows what, by the ordinary tabular method, it takes a series of tables to show. In the tabular method it is a difficult matter to determine which of the factors may have the greater effect on the resultant, and it is impossible, without a large number of records and a great amount of sorting and tabulating, to separate all factors being considered in the study and to find the effect that each one would have had had one of the others not been present.

There are other methods than the one herein described of determining the coefficients (Short cuts are possible), but to one not familiar with the work, the use of the data sheet[2] illustrated is very convenient.

Instructions for Use of Data Sheet

For reference purposes in explaining the data sheet the several vertical columns are numbered and the horizontal rows lettered so that the method may be easily followed. These numbers and letters do not appear on the regular data sheet. In explaining the method reference to a certain square on the data sheet will be by column number and the letter of the row in which it occurs. Thus C-21 will occur in column 21, row C.

The use of the data sheet is best explained by means of an example carried through each of the mathematical steps to the finding of the value of the coefficient. As an example, data from one of our tests has been analyzed in order to determine the relation between the outside temperatures and its effect on the temperature of the stable. It is known that such relationship does exist. It would be useless to compare two factors that obviously bear no relation to each other. Because of the lack of space the table of original data has been omitted. Data for 64 (N) periods are used in the illustration.

The factors under consideration are indicated in the spaces provided therefor in the lower right-hand corner of the sheet, the x variable being the outside temperature and the y variable the stable temperature. Also in the lower right-hand corner space is provided for a title or test identification.

Proceeding with the application of the method as follows:

(1) Assume a convenient scale for representation and record the x and y variable. Any scale may be selected which is within the range of the data and can be conveniently represented on data sheets of the size used. The unit adopted should also be in keeping with the significance of the variation of the variables. In this example, one square reading horizontally represents a variation of two degrees in the outside temperature and, reading vertically, of one degree in the stable temperatures.

(2) Indicate these units or scales on the data sheet for the x variable in Row A and for the y variable in Column 1. Then record the available data, or temperatures, in the proper squares according to the scale. For example, an outside temperature of 4 degrees, or between 4 and 6 degrees, would be recorded in Column 15, and an outside temperature of 14 degrees, or between 14 and 16 degrees, would be recorded in Column 20. Similarly a stable temperature of 42 degrees, or between 42 and 43 degrees, would be recorded in Row H. The data gives x and y variables in pairs. Thus if at one reading the outside temperature is 3.6 degrees and the inside temperature is 42.2 degrees the record would appear as a check or dot in square H−14. In recording the data start with the first reading, recording the values according to scale in the proper column and row and continue the operation, recording the successive readings of the entire test.

(3) Add each column (2 to 30, inclusive), and place the sums which represent the x frequencies in Row V; likewise add rows B to S inclusive and record in Column 31, these sums representing the y frequencies.

(4) The sum of the figures in Row V should equal that of the figures in Column 31, and represents the number of pairs of readings. Record this sum (64) in the space marked N in the upper right-hand corner of the data sheet.

(5) Select any column as the arbitrary origin or axis for the x variables. This arbitrary origin may be taken at any interval but it reduces the arithmetical labor to take it as close to the median as possible as this keeps the products of the numbers smaller. The choice of the origin should be made by inspection, because it does not pay to calculate the median especially for this purpose. Draw a heavy line about the column chosen as the origin, in this case Column 16, so as to designate it clearly.

(6) In like manner choose and clearly indicate the origin for y variables (in this case Row I).

(7) The row and column selected as x and y origins are then marked zero in Row W-16 and Column 32-I. The columns are then numbered right and left and the rows up and down from the origins of the x and y variables as shown in Row W and Column 32. This sequence of numbers represents the de-

[2]This form of data sheet is similar to one proposed by L. L. Thurstone, of the Carnegie Institute of Technology.

gree of departure from the origin. Thus the chart is divided into four arbitrary quadrants. The x variables occurring to the left of the y origins are taken as negative, and those to the right of the origin as plus; likewise the y variables below the selected origin are negative and those above plus.

(8) Multiply the two figures occurring in each column in Rows V and W together and record the negative values in Row X and the positive values in Row Y. This is the product of the x variable and its frequency and is designated by the symbol fx. Next multiply the figures in Rows W and X and W and Y and record in Row Z opposite the heading fx^2. There will be no numbers in Column 16, the x origin, and Row I, the y origin, as the product of the frequency (f) and zero is zero.

(9) Perform a similar operation for the y variables and record the results in Columns 33 and 34 respectively, as shown on the sample sheet.

(10) fy^2 Column 35 is the product of figures in Columns 32 and 33 and 32 and 34. The numbers are obtained as follows: In the square B-20, there is one factor four places to the right of the y origin, in square B-21 one factor five places to the right, in square B-25 one factor nine places to the right and in B-28 one factor twelve places to the right; since these are to the right of the origin they carry a plus sign. The numbers in each square are multiplied by the number representing the departure from the origin occurring below it in the same column in Row W, and the sum of the products in Row B is placed in square B-37. The sums of the products of the other rows are obtained in the same manner and the negative products are recorded in Column 36, and positive products in Column 37. For example, Σx (in Row G to the left of the origin)$=(1x-4)+(1x-3)=-7$, recorded in square G-36, and on the right $(1x4)+(2x6)+(1x11)+(1x14)=41$ recorded in square B-37. This operation is repeated for each row.

(11) The sum of figures in Columns 36 (Σx negative) and 37 (Σx positive) are recorded in Columns 38 and 39, depending upon which is the larger, the positive or negative.

(12) Σxy is obtained by multiplying the figures in Column 32 by the summation in Column 38 or 39 for each row and is recorded under Column 40 or 41 under the proper sign as on the sample sheet. Note that the product of two negative factors is positive. (Compare Columns 40 and 41, Rows M and N.) For example, the Σxy (210), which is the product of the y variable and Σx, found in square B-41, is obtained by multiplying 7 (B-32) by 30 (B-39).

(13) The primary table, found at the upper right-hand corner of the data sheet is now made up as follows: Σfx (negative) equals 115, and Σfx (positive) equals 243. These figures are obtained by adding together the numbers in Rows X and Y to the left and right of the y origin, respectively. The total Σfx equals Σfx (positive) plus Σfx (negative), or $243+(-115)=128$.

(14) A similar operation is carried out for Σfy by adding all above the y origin in Column 34, which are positive, and all below the origin in Column 33 which are negative.

(15) Σfx^2 and Σfy^2 are obtained by adding the numbers in Row Z and Column 35, respectively.

(16) Total Σxy (1356) is obtained by summation of the two Columns 40 ($-\Sigma xy$) and 41 ($+\Sigma xy$) as recorded at the upper right-hand corner of chart as 38 and 1394. The substitution of values may now be made, and the calculation completed care should be taken to record the negative and positive values correctly.

The numbers which have been recorded in the table of summations may be substituted directly in the formula given. From this point on one proceeds by formula and the steps are evident. The final result gives the coefficient of correlation, r, which in this example is .693.

This result indicates an effective relationship between the two variables and that they are directly proportional. The relationship of the two variables may be shown graphically by grouping and averaging the factors and passing a line through the points representing the averages, or as is done in this case, by passing a line through the point of intersection of the average temperature and the average stable temperature at an angle of which the above correlation value is the tangent. In this case the average of the outside temperature is 10.6 degrees and average stable temperature is 41.2 degrees.

The regression factor is next obtained by substitution of values in the formula: $X_r=(r\times x\sigma_x)\div(y\sigma_y)$, where x and y are the scale value of the two factors. This shows the proportion of variation of one factor in relation to the other. (See table previously given.)

The probable error may be determined and is commonly used to find out how closely the individual reading may be expected to agree with the general average. The probable error is obtained by substitution in the general formula $E_r=\pm[.6745\ (1-r^2)\div\sqrt{N}]$, and the result in this case is ±0.04. This is small in proportion to the number given for "r."

Partial Correlation

A study in which many factors are concerned is not complete until it is determined, in the manner just explained, whether or not an apparent correlation is due to the fact that each of two variables or factors under consideration is correlated with another or even several other variables. For example, in our ventilation study the volumes of the air removed is dependent upon the temperature also on wind velocity, etc. The partial correlation coefficient would show the relationship between the outside temperature and stable temperature had there been no wind. This coefficient can be determined by the use of a standard formula. A detailed description of how it is done is too long to be included in this article, and the reader is referred to standard textbooks and the reference previously given. The extent to which this may be used will depend on the data available and the knowledge of the influence of the several factors operating singly or collectively.

This discussion is intended to bring to the attention of the agricultural engineer an old method which promises to be very serviceable in the solution of new problems. The study and interpretation of ventilation test data is very complicated. It is sometimes impossible to measure the varying factors quantitatively, but even in such cases a qualitative analysis is of value. This method enables one to pick out the dominating factors and to study the conditions under which they dominate.

Term "Agricultural Engineering" Standard in U. S. D. A.

OF SPECIAL interest to the agricultural-engineering profession is the action recently taken by the editor of "The Experiment Station Record," published by the Office of Experiment Stations of the U. S. Department of Agriculture, to change the term "rural engineering," as used in "The Experiment Station Record," to "agricultural engineering." We are quoting a letter addressed to Prof. R. U. Blasingame by the editor, which is significant and which it is hoped will pave the way for the standardization of the term "agricultural engineering" in all the land-grant colleges of the country. Such a step would be of tremendous importance in advancing the status of the agricultural-engineering profession.

"Dear Prof. Blasingame:

"Your letter of June 17, addressed to Dr. Allen, has been referred to me for reply. I have delayed an answer until the return to Washington of our specialist in rural engineering, Mr. Trullinger. On consultation with him and with others, I find that there is a general feeling that the points made in your letter are very pertinent and convincing. The term "rural engineering" was originally adopted for use in the "Record" in the expectation that we would abstract not only articles in agricultural engineering, but those not directly agricultural but pertaining to rural conditions, and that the broader term would, therefore, cover the section more adequately. In practice, such articles have been less numerous than anticipated, and it appears that we may as well utilize the term which is being so generally and very properly adopted in college and station organizations.

"It so happens that we are just commencing a new volume of the "Record," so that the present seems the most appropriate time to make the change. We are, therefore, arranging to rechristen the department beginning with our issue for July 1925. We appreciate your bringing the matter to our attention.

Yours very truly,

H. L. KNIGHT, Editor."

A.S.A.E. Tractor Testing and Rating Code

FOR several years the engineers of the tractor industry made real efforts to formulate a standard method or procedure for the testing and rating of farm tractors. The fact that tractor development was still in its early stages naturally made this objective difficult of accomplishment. The efforts of the engineers, however, seemed to have been crowned with success when the American Society of Agricultural Engineers, on the recommendation of its Committee on Tractor Testing and Rating, the membership of which was comprised of agricultural engineers from the tractor industry and the state agricultural colleges, adopted what is known as the "A.S.A.E. Tractor Testing and Rating Code." Early this year the Committee on Tractor Testing and Rating recommended some minor revisions in the code, which were approved by the Council of the Society. At its meeting last April the tractor and thresher department of the National Association of Farm Equipment Manufacturers approved the A.S.A.E. Code and recommended its general adoption by the tractor industry. The code has also been approved by the standards committee of the Society of Automotive Engineers and by that organization as a whole at its annual meeting held in June of this year.

The code in its latest revised form is as follows:

A.S.A.E. Tractor Rating Code

Tractor Rating Specifications

Belt Rating. The belt horsepower rating of the tractor shall not exceed ninety (90) per cent of the maximum load which the engine will maintain by belt at the brake or dynamometer for 2 hours at rated engine r.p.m., the test to be carried out as specified herein.

Drawbar Rating. The drawbar rating of the tractor shall not exceed eighty (80) per cent of the maximum drawbar horsepower developed at a rate of travel recommended for the ordinary operation of the tractor, under conditions of testing as specified herein.

Testing Procedure

Nature of Tests. The following rating tests are to be conducted in the order given on three or more tractors picked at random from factory stock run by the engineer or engineers conducting the test; the averages of all tests are to be used in determining the results:

Test A (Limbering up Run). Before a test is undertaken it is important that the tractor shall have been in operation for a sufficient length of time to attain proper operating conditions throughout so that the results of the test shall express the true working performance. The tractor or tractors to be tested shall therefore be submitted to "limbering-up" runs on the drawbar of twelve or more hours' duration. Drawbar loads of approximately one-third, two-thirds, and full load shall be pulled by the tractor during the runs, each load being drawn for approximately an equal length of time, the lighter loads being used first.

Test B (Maximum Brake Horsepower Test). The tractor engine is to be tested in the belt with the governor set to give full opening of governor valve, and the carburetor set to give maximum power at rated engine crankshaft speed. (The rated speed is that which the manufacturer recommends for the engine under normal load.) The test shall begin after the temperature of the cooling fluid and other operating conditions have become practically constant. The duration of this test shall be 2 hours of continuous running with no change in engine adjustments. If the speed should change sufficiently during the test to indicate that the operating conditions had not become constant when the test was started, the test will be repeated with the necessary change in load. (The term "load," as used in this connection, means pounds on dynamometer or brake scale.) Minor changes in load to be made to maintain rated speed and the average load and average speed for the period shall be used in computing the horsepower. All belt horsepower tests must be made with an electric dynamometer, or with an accurately tested Prony brake or other accurate power-measuring device. Correction shall be made for temperature and altitude effect on horsepower output. Standard conditions of barometric pressure of 28.6" Hg. and a temperature of 70° F., or 530° abs. T, shall be used.

The following correction formula[1] shall be used:

$$B\text{-}Hp_c = B\text{-}Hp_o \times (Ps \div Po) \times (To \div Ts)$$

where $B\text{-}Hp_c$=corrected brake horsepower
$B\text{-}Hp_o$=observed brake horsepower
Po=observed barometric pressure in inches of mercury
Ps=standard barometric pressure in inches of mercury
To=observed absolute temperature in degrees Fahrenheit
Ts=standard absolute temperature in degrees of Fahrenheit

Test C (Maximum Drawbar Horsepower). After the tractor has attained proper working conditions it shall be subjected to a series of drawbar tests preferably on level ground, and of such a nature that it will provide a firm footing and offer tractive resistance simulating that of grain stubble ground in good plowing condition. The loads shall be successively increased or decreased to a point where the tractor can sustain a constant pull for a distance of not less than 1000 feet with

[1]In the correction formula 70 degrees F. is used instead of 60 degrees F., and 28.6 in. Hg. instead of 30 in., since these figures conform more nearly to the conditions as found throughout the tractor region of the Middle West. If a rating is made on corrections made at 30 in. Hg. and 60 degrees F., the rating may be higher than the power actually delivered in a test. If the ordinary accepted standards of 30 in. Hg. and 60 degrees F. are insisted on, then the only alternative will be to drop the percentage figures back to 80 per cent for the belt or brake horsepower and 75 per cent for drawbar horsepower.

TRACTOR RATING TEST FORM — BELT HP LOG SHEET

NAME, MODEL & RATING ______
ENGINE NO ______ CHASSIS NO ______
ENGINE NAME ______ RATED RPM ______
NO CYLS ____ BORE ____ IN STROKE ____ IN DISPL (D) ____ CU IN
CARBURETOR SYSTEM ______
IGNITION SYSTEM ______
FUEL ______ SP GR ______ AT 60°F
DYNAMOMETER ______ ARM (R) ______ FT
ROOM TEMP ____ °F BAR ____ IN HG HUMIDITY ____ %
ENGINE PULLEY DIA ____ IN. CIR. (C_1) ______ FT
BRAKE PULLEY DIA ____ IN. CIR. (B_1) ______ FT
BELT USED ______
PLACE OF TEST ______ DATE ______
OBSERVERS ______

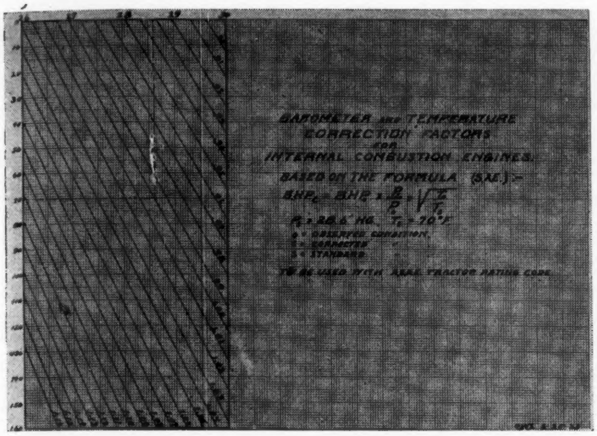
RUN NUMBER	SYMBOL	FORMULA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	AVER
TIME STARTED																	
TIME OF RUN MIN	t																
ENG COUNTER START	C_0																
ENG COUNTER STOP	C_t																
AV ENG RPM	N	$\frac{C_0-C_t}{t}$															
BRAKE COUNTER START	B_0																
BRAKE COUNTER STOP	B_t																
AV BRAKE RPM	N_1	$\frac{B_t-B_0}{t}$															
ENG PULLEY SUR SPEED	S_1	$C_1 N$															
BRAKE PULLEY SUR SPEED	S_2	$B_1 N_1$															
BELT SLIP %	S	$\frac{S_1-S_2}{S_1}$															
BRAKE LOAD AT ARM R	P																
TORQUE LB FT	T																
BRAKE HORSEPOWER	BHP	[illegible]															
WT FUEL START LB.	W_0																
WT FUEL END LB	W_1																
FUEL USED LB IN TIME t	W	W_0-W_1															
LB FUEL PER BHP HR	F	$\frac{60W}{t\,BHP}$															
AIR TEMP TO CARB F°																	
TEMP JACKET WATER IN F°																	
TEMP JACKET WATER OUT F°																	

TRACTOR RATING TEST FORM — DRAWBAR HP LOG SHEET

NAME, MODEL & RATING ______
ENGINE NO ______ CHASSIS NO. ______
ENGINE NAME ______ RATED RPM ______
NO CYLS ____ BORE ____ IN. STROKE ____ IN DISPL (D) ____ CU IN
CARBURETOR SYSTEM ______
IGNITION SYSTEM ______
FUEL ______ SP GR ______ AT 60°F
DYNAMOMETER ______
AIR TEMP ____ °F BAR ____ IN HG HUMIDITY ____ %
TYPE LUGS ____ SIZE ____ DRIVE WHEEL DIA ____ IN
*DISTANCE PER REV OF DRIVE WHEELS ON TEST GROUND (d) ____ FT
KIND & CONDITION OF SOIL ______ DIST OF RUN (d_1) ____ FT
PLACE OF TEST ______ DATE ______
OBSERVERS ______

RUN NUMBER	SYMBOL	FORMULA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	AVER
TIME FOR RUN MIN.	t																
ENGINE RPM	N																
L. WHEEL COUNT START	C_{L_0}																
L WHEEL COUNTER STP	C_{L_1}																
NO. REVS L. WHEEL	R_L	$C_{L_1}-C_{L_0}$															
R. WHEEL COUNT START	C_{R_0}																
R. WHEEL COUNT STOP	C_{R_1}																
NO. REVS. R WHEEL	R_R	$C_{R_1}-C_{R_0}$															
AV. NO. REVS. R & L WHEELS	R	$\frac{R_L+R_R}{2}$															
DISTANCE BY DRIVERS	D	dR															
WHEEL SLIPPAGE %	S_w	$\frac{D-d_1}{D}$															
AV DRAFT LBS	P																
SPEED FT PER MIN	f	d_1/t															
SPEED MI. PER HR	M	$f/88$															
DRAWBAR HORSEPOWER	DB HP	$\frac{P \times f}{33000}$															
TEMP ATOM F°	F_a																
TEMP JACKET WATER OUT	F_w																

*SEE CODE FOR METHOD



the average engine r.p.m. maintained with 5 per cent of its rated full load speed and a wheel slippage of not more than 10 per cent, the wheel slippage to be secured as follows: The tractor shall be driven without any drawbar load for a distance sufficient to give 10 revolutions of the drivewheels. This distance is then accurately measured and is used as the basis for computing wheel slippage. The number of revolutions of all drivers shall be counted for the entire distance through which the load is pulled. The drawbar pull shall be measured by means of an accurately calibrated draft dynamometer or draft measuring device placed between the tractor and the load. The actual distance traveled shall be used in calculating the horsepower, no allowance being made for wheel slippage. During this test the tractor shall be run in the gear recommended for plowing under favorable conditions.

Fuels

These tests will be made on the lowest commercially available grade of fuel which the manufacturer recommends.

Lubricants

The lubricants used in these tests shall be such as are regularly recommended by the manufacturer for the tractor.

Belts

The belt or belts used in these tests shall be such as the manufacturer recommends for use with the tractor in ordinary operation. No allowance will be made for belt losses.

A.S.A.E. Tractor Testing Code

Testing Procedure

Nature of Tests. The following tests are to be conducted on one or more tractors picked at random from factory stock run; records of fuel consumption are to be taken during all tests except Test A:

Test A (Limbering-up Run). Before a test is undertaken it is important that the tractor shall have been in operation for a sufficient length of time to attain proper operating conditions throughout so that the results of the test shall express the true working performance. The tractor or tractors to be tested shall therefore be submitted to a "limbering-up" run on the drawbar of twelve or more hours. Drawbar loads of approximately one-third, two-thirds, and full load shall be pulled by the tractor during the run, each load being drawn for approximately an equal length of time, the lighter loads being used first.

Test B (Maximum Brake Horsepower Test). The engine is to be tested in the belt with the governor set to give full opening of governor valve, and the carburetor set to give maximum power at rated speed. (The rated speed is that which the manufacturer recommends for the engine under load.) The test shall begin after the temperature of the cooling fluid and other operating conditions have become practically constant. The duration of this test shall be two hours of continuous running with no change in load or engine adjustments. (The term "load" as used in this code, in connection with brake tests, means pounds on dynamometer or brake scale.) If the speed should change during the test enough to indicate that conditions had not become constant when the test was started, the test will be repeated with the necessary change in load. If, however, the speed should tend to increase only slightly during the progress of this test sufficient load shall be added to maintain the speed constant and the average load for the period shall be used in computing the horsepower.

Test C (Rated Brake Horsepower Test). The engine is to be tested in the belt at rated speed with carburetor to be adjusted for best economy. The load is to be such as to give not more than eighty (80) per cent of the horsepower obtained in Test B. The test shall begin after the temperature of the cooling fluid has become constant and shall continue for two hours' continuous running with no change in load or engine adjustment.

Test D (Varying Load Tests). The engine is to be tested in the belt with all adjustments as in Test C with no stops. The total running time shall be one hour and ten minutes, divided into seven ten-minute intervals as follows:

(a) 10 minutes at load as in Test C
(b) 10 minutes at maximum load
(c) 10 minutes at no load
(d) 10 minutes at one-fourth load
(e) 10 minutes at one-half load
(f) 10 minutes at three-fourths load
(g) 10 minutes surging loads varying suddenly from maximum load to no load and other varying loads between these extremes

The object of this test is to determine the efficiency of governor action or speed control and to determine fuel consumption at different loads. If the load changes make readjustments necessary, the final report of the test will state that such was the case.

Type of Brake

All belt horsepower tests must be made with an electric Prony brake or other accurate power-measuring device.

Drawbar Tests

Drawbar tests are to be conducted after the brake tests are completed. The drawbar tests are to be conducted on as near level ground as is available. The ground shall be firm and of such a nature as to provide sufficient tractive resistance to permit the tractor to exert its full power. The loads shall be successively increased or decreased to a point where the tractor can sustain a constant pull for a distance of at least 1000 feet with the average crankshaft revolutions per minute maintained within 5 per cent of its rated full load speed and a wheel slippage of not more than 10 per cent. The wheel slippage is to be determined as follows: The tractor shall be driven without any drawbar load for a distance sufficient to give 20 revolutions of the drivewheels. This distance is then accurately measured and is used as the basis for computing the wheel slippage. The number of revolutions of all drivers shall be counted for the entire distance through which the load is pulled.

Other drawbar tests shall be carried out in a similar manner as above, except the determination of the amount of load. This can be determined before such tests are begun by using any desired portion of the rated load. The rated load shall be not more than eighty (80) per cent of the maximum load.

If fuel consumption records are desired on the drawbar test, then the test shall continue for at least two hours with no stops. The amount of fuel shall be determined by starting with the fuel tank full. At the conclusion of the test the tank shall be refilled, carefully weighing the amount required to refill and converting it to U. S. standard gallons at 60° F. Draft and slippage records shall be taken, as for the maximum test, at 30-minute intervals during the test.

Measuring Device

The drawbar pull is to be measured by means of an accurately calibrated draft dynamometer or draft measuring device, properly placed between the tractor and the load being drawn.

Miscellaneous Tests

This may include any desired tests not included in the above outline. Such tests shall be so conducted that the results will be accurate and reliable.

(Continued on page 218)

Research in Agricultural Engineering

A department conducted by the Research Committee of the American Society of Agricultural Engineers

The Problem of Research in Farm Equipment

By R. W. Trullinger

Mem. A. S. A. E. Specialist in Agricultural Engineering, Office of Experiment Stations, U. S. Department of Agriculture

NOTE: This paper represents the attitude of the A.S.A.E. Committee on Research in Agricultural Engineering on the subject of research in the field of farm equipment. It was presented at the meeting of the Farm Power and Machinery Division of the Society held at Chicago, December 3, 1924. The purpose of Mr. Trullinger's paper is briefly to outline the situation and need with respect to research in farm equipment and to suggest, in a general way, the lines along which efforts in this direction should proceed. It suggests, as the logical basis of procedure, the harmonious cooperation between the profession of agricultural engineering, the farm-equipment manufacturing industry, and the agricultural industry. It should be made clear, in this connection, that the term "agricultural engineer" refers to any engineer whose primary function is the application of engineering to agriculture, whether it be in the development of farm machinery and allied equipment in a manufacturing organization; in teaching, research, or extension in agricultural engineering at an educational institution; or in any branch of the agricultural-engineering profession. The Committee on Research welcomes suggestions and criticisms of its ideas on research in farm equipment and invites A.S.A.E. members and others to offer recommendations for both a general research program and specific research projects that should be undertaken.

THE problem of research in farm equipment may be approached by considering, as a fundamental premise, that agriculture is a basic industry, the mechanical requirements of the processes and practices of which should be met by agricultural engineers and manufacturers of farm equipment.

This fundamental conception then means specifically that the industry of agriculture, the profession of agricultural engineering, and the farm equipment manufacturing industry are related in a somewhat triangular manner. This means that each is dependent upon the other two for its stability.

To better visualize this relation, it may be assumed that when the three form an equilateral triangle, each is operating at the optimum of its efficiency and economy. The slightest fluctuation in the stability of any of the three angles of such a triangle immediately influences the stability of the other two angles, and the triangle is no longer equilateral.

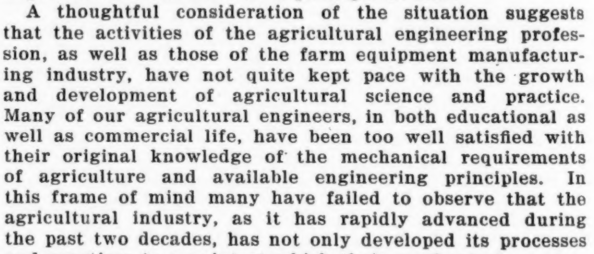
Perhaps this conception is not exactly based upon fact but in principle it is believed to be a sound conception. Regardless of the nature of the triangular relation, however, it is a well-established fact that instability in the agricultural industry has a bad influence upon the equipment manufacturing industry and upon the profession of agricultural engineering.

The problem of research is obviously then to find out how to establish and maintain equilibrium among these three activities. This means then that our study must go farther than a mere consideration of the draft power required for a plow, the most profitable method of manufacture or sale of a silage cutter, or the quickest method of adjusting a corn planter. We must begin to think deeply and fundamentally in terms of why these three groups of activity are in existence, and with this as a basis, begin to work out ways and means whereby they can continue to exist with an optimum of mutual benefit as well as individual profit.

The agricultural industry has advanced by leaps and bounds during the past generation. Agricultural practices and processes have been developed through the medium of science and education until the mechanical requirements for their optimum performance can no longer be completely met by available equipment in many cases. Previous to this time, manufacturers did their best to supply equipment with which to perform the various agricultural operations, and when the extremely limited knowledge of the fundamental requirements of agriculture with which they had to work is considered, it must be admitted that they did their work remarkably well. However, when the agricultural industry itself did not know exactly what it needed it was not surprising that much equipment was produced which was short lived. In addition the agricultural industry was forced to make the best use possible of available equipment, which practice frequently required the modification or warping of the process in order to make the use of some equipment possible.

Obviously the agricultural industry was too busy to establish the facts as to its mechanical requirements. Likewise the equipment manufacturing industry had its hands full with the details of manufacture and sale which would insure a living profit. The need for the agricultural engineer to act as a medium between the farmer and the manufacturer thus became plainly evident, and in this way the triple alliance was formed in principle at least.

A thoughtful consideration of the situation suggests that the activities of the agricultural engineering profession, as well as those of the farm equipment manufacturing industry, have not quite kept pace with the growth and development of agricultural science and practice. Many of our agricultural engineers, in both educational as well as commercial life, have been too well satisfied with their original knowledge of the mechanical requirements of agriculture and available engineering principles. In this frame of mind many have failed to observe that the agricultural industry, as it has rapidly advanced during the past two decades, has not only developed its processes and practices to a point at which their mechanical requirements call for special attention and specific treatment, but has also developed some highly specialized engineering problems. It has been even more easy for many manu-



facturers to overlook these facts in the rush of business and competitive commerce.

These advances, with few specific or well-thought-out plans for meeting the resulting modified agricultural requirements, have naturally resulted in the gradual partial or complete obsoletion of considerable farm equipment. This did not seem to be felt so badly by the manufacturing industry until it was accompanied by a marked agricultural depression. However, the available evidence would indicate that hard times for the equipment manufacturing industry are due about as much to the failure of the agricultural engineer to provide adequate basic facts and of the manufacturer to ask for them as to a temporary instability in the agricultural industry.

Regardless of who is to blame for instability in our triangle, the fact remains that the present duty of the agricultural engineering profession and the equipment manufacturing industry is to establish and follow lines of future procedure which will prevent further instability. A rapidly growing and scientifically developing agriculture is advancing specialized requirements of its practices and processes which can no longer be met by rule-of-thumb engineering principles and equipment manufactured by guess and past empirical knowledge. The sale of equipment is gradually coming to depend upon specific needs therefor, which needs must be specifically met by the equipment placed on sale. Manufacturers are also being forced to conserve in both labor and materials in order to operate at a reasonable profit. This indicates the absolute necessity of ultimate standardization. Intelligent, practical, and profitable standardization cannot be effected until the equipment to be standardized is fundamentally sound.

This means then that agricultural engineers must develop a new and searching viewpoint. They must cooperate closely with specialists in all lines of agriculture and be quick to recognize the modified and specialized mechanical requirements of agricultural practices as they are scientifically developed. They must meet these requirements by means of engineering science and the resulting modified or new engineering principles must be made available to manufacturers of farm equipment as the basis for their future business.

In fact, there should be as close cooperation between the agricultural engineers and the equipment manufacturers as between the engineers and the agricultural specialists. There should be such close harmony that the manufacturer can maintain his plant in a stage of gradual development to keep pace with the equally gradual development of agricultural practices without the necessity of actual contact therewith.

In Fulfilling His Duty the Agricultural Engineer Aids Both Farmer and Manufacturer

The responsibilities of the agricultural engineer are not confined to cooperation and research, however. Once he has established the facts and principles of ways and means to meet the mechanical requirements of agricultural practices, it is his duty to show the farmer, by means of teaching and extension procedure, that equipment manufactured on the basis of such principles will meet specific needs. In addition when he becomes acquainted with specific requirements, he should immediately determine whether or not any of the equipment at present manufactured fully meets such requirements before he inaugurates work to develop new equipment. By doing his duty thus intelligently he may aid the farmer immediately, aid the manufacturer in disposing of his stocks of equipment where they will do the most good, and incidentally conserve his own time. If available equipment does not meet the requirements his task of providing the specifications for such equipment by research procedure is clearly cut.

Thus we have the stable triangle of agriculture, engineering, and manufacture. Agriculture provides the specific requirements, the engineer by research procedure establishes the facts and principles to meet these requirements, and the manufacturer transmits them to the farmer in the form of usable equipment bearing the stamp of approval of a science which is based upon the demands of actual practice.

There are probably many practical difficulties to the establishment of such a triangle. But who can deny that the agricultural engineer is the logical medium for the establishment of scientific facts and principles to meet the requirements of agriculture for mechanical equipment? And who can deny that the manufacturer is the only logical medium for transmitting these scientific principles to the farmer in the form of usable equipment?

Certainly the farmer cannot manufacture his own equipment, even if he were trained to understand the scientific principles involved. Anyhow his business is farming. The average manufacturer is quite busy enough with manufacturing and selling and keeping his head above water without undertaking research to provide a basis for his manufacture. It is self-evident that he desires to manufacture only the right thing and that he desires to keep abreast of the times, so that he can continue to manufacture the right thing in the right way.

What then is the objection to the formulation of the triangular relation outlined? It would seem that one of the greatest obstacles to such a relation is the natural reticence of both engineers and manufacturers to meet each other half way and become acquainted with each others' problems and troubles. There is also that tendency in still some cases for the engineer to hesitate to get better acquainted with agricultural scientists at large.

Let the Aim Be Toward the Optimum in Agricultural Equipment.

In the meantime the farmer is the goat. As his knowledge increases, his practices develop and his mechanical problems grow. How long must he wait for his engineering and manufacturing friends to get together in a constructive way? It seems that the time is now ripe for the agricultural engineer to crawl out of his shell of professional and technical reserve and for the manufacturer to melt his armor of business disregard for scientific facts, and for the two to get together in a friendly and constructive way and work out these engineering and manufacturing problems to the best interest of all concerned with the objective of establishing the optimum in agricultural practices. The present tendency of the engineer to in many cases overlook the fundamental requirements of the farmer and to refuse to become interested in the problems of the manufacturer is obviously as unjust to the manufacturer as to the farmer. The frequent disregard by the manufacturer for the proper functions of the engineer is mainly a great injustice to himself.

These attitudes of the engineer and the manufacturer are obviously unjust to the farmer who looks to them to provide the tools for the building up of his industry. Why cannot the engineer and manufacturer join forces? Let the engineer interest himself not only in the needs of the farmer but also in the problems of manufacture and sale. Let his research see clear through to the ultimately practical production of required equipment. Let the manufacturer give whole-hearted and substantial support to the engineer, whether in public or private service, and profit by his research and extension activities. Let both the manufacturer and engineer aim toward the optimum in mechanical equipment for the farmer.

Such ideal cooperation seems remote at first glance, but it is quite possible. The problems of the engineer and manufacturer which are of mutual interest are mainly technical and professional. A common ground for a meeting of their minds is provided by the American Society of Agricultural Engineers. All agricultural engineers are interested in the substantial building up of their profession along sound fundamental lines. Likewise thinking farm equipment manufacturers desire to build their business upon a sound fundamental basis to insure a substantial development in the future. Both engineer and manufacturer have the common aim to profit personally by following a constructive program. Such a program can best be developed by working in harmonious cooperation, and the best method of effecting such cooperation is by undertaking active membership in the American Society of Agricultural Engineers.

The Power Take-Off for Tractors

(Continued from page 208)

due to its limited turning angles and further due to the slowing down and quickening of the power four times for each revolution while deflected. I wrote to some fifteen or twenty different companies that were building hook joints, asking at what turning angles they guaranteed their joints and to tell me what efficiency of power they could deliver when deflected 15, 30, 45, 60 and 90 degrees. No manufacturer would guarantee their joints past 15 degrees and one company which builds one of the best hook joints stated that their joints showed 84 per cent efficiency when deflected 15 degrees, 52 per cent efficiency when deflected 30 degrees and transmitted power in theory only when deflected 45 degrees. I tried connecting two hook joints up close together but failed to get any considerable efficiency.

In my experiments of building seven different models of power take-offs I developed a nest of gears that would transmit an even flow of power without pulsation regardless of high turning angles. Six of these models have been extensively field tested. A total of seventeen of our power take-offs are now in use on fifteen different farms.

A comparison of efficiency of our hook joint jobs with our gear joint jobs shows that the hook joint jobs have good efficiency while driving straight ahead, but when crossing rice levees and while turning corners the hook joint jobs lose a great deal of power besides delivering such a jerky flow of power that the sprocket chains of the binder are frequently thrown off the sprockets at corners. Our patented gear joint overcomes all such troubles.

We made the following practical comparative field test of the two different types. We had a Fordson equipped with one of our gear joint jobs operating an 8-foot binder in a field of rice. The levees were high and the ground was soft yet we seldom had to use low gear. We replaced our gear joint model with our hook joint model whereupon we frequently had to use low gear in order to get over the rice levees. When the hook joint was deflected some 15 degrees as the front wheels were nearing the top of the levees the loss of power was great enough to make it necessary to use low gear. Likewise when the rear wheels neared the top of the levees the hook joint would be deflected in the other direction sufficiently to greatly reduce the efficiency of the transmitted power making the shifting into low gear necessary.

The tumbling shaft should be some 16 to 20 inches high in the rice territory so as not to come in contact with the levees. It is desirable to have the tumbling shaft located over the drawbar member so as to be able to turn to right or left without telescoping complications. Such a set-up also enables the heavier drawbar member to stop the lugs of a tractor while turning thus preventing the lug of the rear wheel from bending the tumbling shaft. The gear universal joint should be located just far enough back of the tractor so as to throw the tumbling shaft out of reach of the rear tractor lugs while turning at the shortest angles.

We have tried speeds from 175 to 480 r.p.m. A speed of about 350 r.p.m. seems to be ideal for operating slower moving machines like grain elevators and also gives less vibration to the tumbling shaft when set up to machines like grain binders.

You noticed in one of the pictures shown on the screen that we have developed a telescoping tumbling shaft and binder tongue member so that when the tractor begins to bog down the latch on the binder tongue can be released and the tractor can advance about 3½ feet to a new footing before pulling out the binder. The forward and rear members of the tongue cannot slip apart, but the tumbling shaft members easily slip apart in case it is necessary to detach the tractor from the implement.

We have given considerable attention, in designing our power take-off so that it may be quickly attached to the tractor with the tractor kit of tools. It is to be hoped that the binder manufacturers will develop some simple method of receiving power from tumbling shaft. Perhaps the simplest method of doing this would be to have the pitman wheel cast for a sprocket chain and have a suitable malleable iron bracket to support another sprocket just above which sprocket would be connected to the tumbling shaft. Such a bracket could likely be rigidly attached to the binder frame with two or three bolts.

In the matter of lubrication, we have designed our job so that practically all the moving parts operate in a bath of oil. Farmers are prone to use motor oil on this job, due perhaps to the fact that they have more of it than of other kinds of lubrication.

We have kept the matter of safety constantly in mind, since if there are any projections on the tumbling shaft, a frazzled trouser leg would be sure to result in serious accidents as the operators climb in and out of the tractor seat, over the power take-off.

Our power take-off has been designed so as to facilitate manufacturing procedure, since a popular selling price can only be made possible by manufacturing economy. We use some seventy standard Ford parts and a few International Harvester parts in the construction of our device.

Mr. Kranich: I would like to ask Mr. McGrew a question. He said that they drove to the front end of the binder crankshaft. How do you do that?

Mr. McGrew: We made an extension on the pitman shaft; we ran the pitman shaft clear through and in front, and then we put on a universal joint and let this pitman shaft running to the back of the binder drive the rest of the binder.

Mr. Kranich: What speed do you use?

Mr. McGrew: We use a speed of 350 r.p.m. We experimented with all the different speeds from about 200 up to 600 r.p.m., and we find a speed of about 350 r.p.m. the most efficient and the best thing we can find for our device. That is also a clockwise rotation. We understand that there is a counter clockwise rotation used on some machines, but ours is a clockwise rotation, which is used on most all the binders that we have any knowledge of. We do away with an extra set of gears.

Mr. Scarrett: I think the former speaker's remarks regarding the type of driveshaft joint immediately back of the tractor are very good. We have run into the same thing, and I know that an ordinary knuckle type joint is not going to satisfy the requirements there; so, inasmuch as that is one of the elements that we think should be furnished by the implement manufacturer, I think they ought to work up some other type of joint than a knuckle joint, so that you can get into a right-angled position and still transmit power.

Mr. Yerkes: With regard to the percentage of power which should be available for delivery on the power take-off shaft, I think there is a lot of advantage in being able to deliver all of the power there, and I don't see any disadvantage in it. As time goes on, the farmer is finding more and more uses for the power take-off, many that the manufacturer never dreamed of, and a lot of these are for stationary work where they often need the full engine power on the take-off. In field drawbar work, you either have enough power to pull your machine and drive the mechanism, or you haven't, and it doesn't make much difference whether you have allowed 50 per cent, or 75 per cent, or 25 per cent, you either can pull the outfit and drive its mechanism or you can't. I think this question has pretty nearly settled itself, because there are so many times when you want all the power on the power take-off shaft that we must make provision for it.

Another point that deserves serious consideration is the manner in which the power take-off is installed, whether it permits of operation independently of the rear wheels, or whether it can be operated only while the traction wheels are in motion. There is a big advantage in being able to operate the mechanism of almost any machine when the outfit is standing still. For example, if a binder has clogged and you need to clear it, it is a very serious disadvantage if you are not able to run its mechanism with the tractor standing still.

Then, there are times when you are testing it out, when you are getting ready to go into the field, and that sort of thing, when it is very desirable to operate the binder mechanism independently. Then with dusters and sprayers, and many other machines, you want, at times at least, to run the mechanism while the tractor is standing still. I think this has been pretty well demonstrated already in service.

Mr. Jones: Not from the engineering standpoint, but from recollections of actual work of these machines in the field, I think it may be said that in most cases you can proceed on the assumption that a constant speed in revolutions per minute is practical and desirable, regardless of the rate of forward travel of the machine. There are only a few cases in which the rate of travel of the outfit should be related to the rate of rotation of the machine parts. Those that occur to me are seeding machinery, such as the drill that was mentioned, and the manure spreader, in which the rate of spread must be proportional to the rate of forward movement. But in both those cases, and it will probably be found in all cases in which the rate of rotation of the implement must be proportional to the forward travel, it will not be practicable to operate those parts from the power take-off, for the reason that there is a variable factor introduced by slippage of the drivewheels of the tractor. So that in the case of the manure spreader, for example, the apron movement should be actuated from the bull wheels or carrying wheels, while the large part of the power required for operation, namely, by the beater or cylinder, should come by way of the power take-off.

In the case of the drill I question very much whether the power requirements are sufficient to warrant the operation of a power take-off.

Mr. Wiggins: I thought one of the photographs showed a power take-off on an elevator. Is that what it was?

Mr. Ray: Yes, a grain elevator. My investigation shows that there are some two hundred uses to which a power take-off may be put. Another case is elevating road graders used in highway and levee construction. Levee contractors and government engineers give out information that shows that this device would save about $1,000 worth of time, per grader gang, per month during the rainy season or while moving material from silty or sandy pits. At present when the bullwheel of the grader skids in mud, sand or silt, from ten to twenty dump wagons with teams and drivers mark time while the grader plow and elevator is cleared. We also have inquiries for our power take-off to use in connection with stump saws. No doubt the power take-off will enable the tractor to speed up the clearing of cut-over land.

Mr. McCray: I would like to ask Mr. Yerkes or Mr. Zimmerman if they can take the full power of a 15-30 McCormick-Deering tractor, for instance, on that shaft.

Mr. Yerkes: Yes, that is, on the power take-off shaft of the tractor itself.

Mr. McCray: The outfit is designed to take that much torque, is it?

Mr. Yerkes: Yes. We have had a lot of cases where these tractors have gone out to farmers and other users who put them at jobs where they need the full engine power back on the power take-off. One case I might mention is in running sawmills. They often use a pulley on the power take-off shaft, in addition to the regular

belt pulley. The pulley on the take-off shaft will drive the cut-off saw, or some other machinery and will often take, for short periods, a big percentage of the engine's power.

As I said, there are a lot of advantages in having the full power available there, and I don't see any good reason why we shouldn't make it available. It won't cost very much more, surely.

There is one point I don't think has been touched upon, and that is the possible advisability of providing for a change in the speed and direction of rotation of the take-off shaft, either through a nest of gears or some other means. We need a standard speed as mentioned—that must be arrived at—but isn't it entirely possible that different machines, may need a very different rate of rotation? It may be worth considering some means of changing the speed of the shaft within certain limits; perhaps there ought to be a standard range of speeds. Tractor users are finding so many uses for these take-offs that the manufacturers never thought of at first, that, as someone said here today, now is the time to settle these things, before the different manufacturers get out thousands of tractors with a lot of different take-off connections and a lot of different speeds and then have to start in and standardize, making it more expensive for everybody.

Mr. McCray: How much power will your slip clutch transmit?

Mr. Yerkes: We use several different sizes of slip clutches, and all of them are adjustable. On the binder and corn picker, for example, there is a slip clutch on the tumbling rod which connects to the power take-off shaft of the tractor. This can be tightened to transmit up to eight or ten horsepower. Then there are similar but smaller clutches on other shafts about the various machines. On the harvester-thresher, there are five of these slip clutches, but none on the main driving shaft which connects directly to the threshing cylinder. This is because the momentum of the cylinder is as great or greater than that of the moving parts of the engine, and a slip-clutch would be of no value there. The harvester-thresher is one case where provision must be made for transmitting approximately the full engine power to the drawn machine, for there will be occasions, though perhaps of very short duration, where such power will be required.

Mr. Kranich: There are some combined harvester-threshers being run experimentally, I believe, by power take-off shafts which will require considerable power to operate, perhaps 18 or even 20 horsepower. On a 15-30 tractor that might afford enough power to do that. But I question Mr. Yerkes' statement that their power take-off shaft, not the tractor shaft, but the one from the tractor, will transmit anywhere near full engine torque. It is a very light shaft and has been designed for binders and corn binders, etc., which ordinarily are run with a five or six horsepower engine. To transmit full engine power through this shaft is almost impossible, although the shaft on the engine will carry it, because it is full size.

Chairman Wirt: I am wondering if some of you wouldn't like to express an opinion on the desirability of using the screw connection or the spline connection. That has just been mentioned in passing. I think it is something to be discussed too.

Mr. Ray: We have tried screw, spline and break pins. A good screw job seems to be most satisfactory and the most economical for us.

Chairman Wirt: What about removal—if you screw it on and the outfit has been used for some time, I mean?

Mr. Ray: Farmers take the shaft off with the rest of the unit. The tumbling shaft is folded over the rest of the unit like a jack knife.

Chairman Wirt: Suppose they took it off at the connection. How would it come off?

Mr. Ray: The farmers where we have been experimenting, in the Stuttgart, Arkansas, rice belt, all have irrigation plants which necessitate the use of Stilson wrenches. A Stilson wrench quickly disconnects, or they can use any wrench on the one-inch key steel rear member of the telescoping tumbling shaft.

Mr. McGrew: We use the spline system. We also tried the screw, but the spline system seems to work on our device the better of the two. We haven't had any trouble with it at all.

Mr. Zimmerman: I would also like to suggest the consistency of using the spline rather than the screw system. That is the most logical, the most highly developed from a mechanical standpoint, and I think our Society ought to stand back of and support what seems and what has proved to be the most logical from a mechanical standpoint. Likewise in regard to the speeds of rotation, I think if you analyze the whole situation, you will find an enormous number of possible uses of the power take-off, yet the greater part of the use comes in operating mowers and binders, and we practically are limited on those two operations to certain cutting speeds of the knives. Hence, it seems to me the logical original speed that we adopt, or at least the predominating speed, should be that which suits these two conditions, mowing and binding.

Mr. Yerkes: There is another point I would like to get in the record. The difficulty of unscrewing the round power take-off shaft from the main driveshaft has been mentioned. I think, where screw connections have been used, in most cases there is a perfectly round surface on the outside of the shaft that carries the female thread. There is no reason why that shouldn't be a hexagon, I believe, so that any suitable wrench could be used to unscrew it, instead of requiring a pipe wrench to do the job. That point would probably come up to the disadvantage of the screw connection if it is adopted; and if it is decided to use the screw, I think we ought to have the hexagon or octagon shape on the outside, so that an ordinary wrench can be used on it.

Mr. Scarrett: I want to say one more word in favor of the spline connection. If you have a screwed-on joint, you have to dismantle the joint in order to unscrew the driving flange. If you have a splined hub in the driving side of the joint, which has a clamping feature in it, that is slipped on and clamped with two bolts, you simply take out the two bolts and disconnect without knocking the drive apart, making use of the telescoping feature of the driveshaft.

Mr. Bates: From the standpoint of the manufacturer, the utilization of the power take-off divides itself into two fields: First, the utilization of the power take-off to drive machinery as at present designed for horse operation, and, second, to develop machinery which is heavier, which has better bearings and which will stand up longer under power drive. Some of the sad experiences with the power take-off have resulted because the power take-off was applied to machines which never were designed to take the power which was transmitted through some of these take-offs to them; that is, they are operated at higher speeds, and the life of the machine is correspondingly reduced. I think that is one of the reasons why some of the power take-offs have been designed to operate as a function of a certain transmission shaft speed rather than as a function of the engine speed itself.

In reference to the amount of torque to transmit on this power take-off shaft, if the present S.A.E. speed of 536 r.p.m. is held to, which is approximately one-half the average four-cylinder engine speed, it would mean that you would have to transmit a torque of twice the normal engine torque through that shaft, and it would appear from the standpoint of expense alone that, if you designed your power take-off to stand such stresses, you would be running into greater expense than would be justified by the installation.

Mr. Kranich: I think that is a splendid point that Mr. Bates brought out, because, as I said before, a combined harvester-thresher is the biggest unit they run with this so far. If anybody does have some immense unit to run with it, that would require a considerable horsepower, then the attachment would become far bigger, but for the attachments that we have now, it seems to me that something along that line to bring down the cost and make it more usable is going to enlarge the scope of the thing and surely considerably help the situation that we are up against now.

Mr. Yerkes: There is one other point I believe should be brought out. A lot of machines, when they are driven with the power take-off, need forward controls. Several of the slides showed two men doing the work which one man ought to do. It is not an economic proposition to have two men operating one binder, especially a six or seven-foot binder, which is the size that a good many men operate when they buy the power take-off and put it on an old binder. There is already some provision, and there should be more provision made, I think, if we are going to continue to use the old horse-drawn equipment, to provide front controls so the tractor operator can control the binder from his seat. Men who have used these controls claim it is no more difficult to operate the levers from the tractor seat than it is to drive a four or five-horse team and operate them from the binder seat.

Mr. McCray: It may not make much difference to take off the full power, but for the fellow who is making it as an attachment and has to make the bearings and shaft and extra gears for that, it makes a considerable amount of difference. Therefore, if we are going to take off the full power of the tractor and make that a recommended practice, we should know it at the beginning.

University of Minnesota Offers Technical Course in Agricultural Engineering

BEGINNING with the college year 1925-26 the University of Minnesota will offer a four-year technical course in agricultural engineering. As approved at a recent session of the board of regents, the course will be administered by the college of engineering and architecture in cooperation with the college of agriculture, forestry and home economics. Students who finish the course will receive the degree of Bachelor of Science in Agricultural Engineering.

The work of the freshman year will be the regular curriculum for all engineers as given in the college of engineering. Sophomores will continue the work in engineering mathematics and other fundamental sciences and also begin some of the specialized lines of engineering in relation to agriculture. In the junior and senior years the work will become more specialized in those phases of engineering having to do particularly with the business of farming.

The instruction in general engineering will be given by men of the regular staff of the college of engineering. The instruction in the more specialized lines will be given by the staff of the division of agricultural engineering of the college of agriculture. Purely agricultural instruction in such departments as agronomy and farm management, animal husbandry, dairy husbandry, agricultural economics, forestry, horticulture, rhetoric and soils will be given by the staffs of those divisions.

"To turn out engineers qualified to work with and for the farmer is the object of the new course," says Prof. William Boss, chief of the agricultural engineering division at University Farm. "The course will cover in a general way the entire field of agricultural engineering; in addition, elective studies will be suggested, especially for upper classmen, embracing three distinct lines of specialization, namely farm structures, farm mechanics and land reclamation."

New A.S.A.E. Members

D. N. Borodin, president and director, Russian Agricultural Agency in America, Inc., New York City.

P. M. Churchill, consulting engineer, Massachusetts Reclamation Board, Elmwood, Massachusetts.

W. A. Clough, engineering department, General Electric Company, Chicago, Illinois.

J. D. Eddy, managing editor, Farm Mechanics Magazine, Chicago, Illinois.

W. H. Hartman, University of Wisconsin, Madison, Wis.

D. G. Miller, drainage engineer, U.S.D.A. Bureau of Public Roads, University Farm, St. Paul, Minnesota.

B. D. Moses, assistant professor of agricultural engineering, University of California, Davis, California.

R. A. V. Nicholson, draftsman, Central Experimental Farm, Ottawa, Canada.

S. A. Norling, consulting drainage engineer, Excelsior, Minn.

F. T. Ransom, E. I. du Pont de Nemours & Company, Lockport, New York.

H. S. Reed, president, American Nile Co., Hollywood, California.

H. A. Wadsworth, assistant professor, division of irrigation practice, College of Agriculture, Davis, California.

Archibald Williams, branch manager, J. B. Colt Co., Rochester, New York.

R. W. Wilson, John Deere Plow Company, McKinney, Texas.

TRANSFER OF GRADE

H. D. Duckett, Houston, Texas.

O. K. Hedden, farm machinery survey, department of agricultural engineering, University of Nebraska, Shickley, Nebraska.

V. A. Michael, Nebraska extension engineer's office, University Place, Nebraska.

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the July issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Franklin A. Beidleman, agricultural engineer, Portland Cement Association, 18 Ridgeway Avenue, West Orange, New Jersey.

H. H. Beningfield, engineer, Cletrac (South Africa) Ltd., Durban, South Africa.

Charles Kirby Fox, consulting engineer, Los Angeles, California.

Albert C. Heine, instructor in agricultural engineering, West Central School of Agriculture, Morris, Minnesota.

Eugene Holcomb, Consumers Power Company, Jackson, Michigan.

Earl G. Johnson, fellow at the University of Nebraska, Manhattan, Kansas.

James C. Marr, associate irrigation engineer, division of agricultural engineering, U. S. Department of Agriculture, Boise, Idaho.

Gottlieb Muehleisen, president and general manager, National Soil Conservation Company, Alma, Wisconsin.

Charles H. Ray, salesman, Austin Western Road Machinery Co., Stuttgart, Arkansas.

Charles F. Shaw, professor of soil technology, College of Agriculture, University of California, Berkeley, California.

Perry T. Simons, drainage engineer, U. S. Department of Agriculture, McGehee, Arkansas.

E. A. Taylor, manager, tractor and heavy machinery department, Bateman Brothers, Inc., Philadelphia, Penna.

Channing Turner, industrial engineer, U. S. Wind Engine & Pump Co., Batavia, Ill.

TRANSFER OF GRADE

Homer H. Doughty, Allenville, Ill. (Student to Junior Member.)

The A.S.A.E. Tractor Testing and Rating Code

(Continued from page 213)

Fuels

All tests will be made on the lowest commercially available grade of fuel which the manufacturer recommends for his particular tractor. All fuel used shall be purchased on the open market and shall consist of the low grades of such fuel commonly sold in the locality, that is, if the tractor is to operate on gasoline, the lowest grade of such fuel commonly sold in the community shall be used. The same is true of kerosene and distillate.

The quantity of fuel used in each part of the test shall be determined by weight and reduced to the United States standard gallon at 60 degrees Fahrenheit. For the brake tests a fuel tank shall be placed on a delicately balanced scale and set at the same height as the fuel tank on the tractor and connected to the carburetor by means of a flexible tube. All fuel used during the test shall be drawn from this tank and weighings made and recorded at regular intervals not more than ten minutes apart during the test.

Lubricants

Lubricants specified by the manufacturers are the kind and grades of lubricants to be used in the different parts of the tractor during the tests.

The quantity of oil used is to be determined by the United States standard gallon, quart or pint measure.

Cooling Medium

The quantity of cooling medium used in the radiator and cooling system is to be determined by measuring the height of the same at the beginning of the test and filling to the same level at the end of the test, weighing or measuring the material added.

A. S. A. E. Employment Service

This service, conducted by the American Society of Agricultural Engineers, appears regularly in each issue of Agricultural Engineering. Members of the Society in good standing will be listed in the published notices of the "Men Available" section. Non-members as well as members, are privileged to use the "Positions Available" section. Copy for notices should be in the Secretary's hands by the 20th of the month preceding date of issue. The form of notice should be such that the initial words indicate the classification. No charge will be made for this service.

Men Available

AGRICULTURAL ENGINEER, 1925 graduate of College of Agriculture, at the University of Illinois, who has specialized in tractors and farm-power machinery and lubrication, and who has had eight years' experience in the operation, repair, and demonstrating of tractors and related farm machinery, desires a position preferably with a farm-machinery manufacturer or oil company. MA-127.

Positions Open

AGRICULTURAL ENGINEER to teach farm buildings, agricultural drawing, rural architecture, and to handle the extension work in farm buildings is needed at Virginia Polytechnic Institute, Blacksburg, Virginia. The work is so arranged that one-half time will be devoted to resident instruction and the other half to extension work. Most of the extension work at present is confined to actual designing of farm structures with some field work. A man is wanted who is capable of developing the extension phase of the work to the highest efficiency. Those interested should write C. E. Seitz, head of the department of agricultural engineering.

SALES ENGINEERS (two) with engineering training wanted to sell retail Fordson industrial tractors in and around the city of Chicago. Ability to recognize a live prospect and to approach factory superintendents, traffic managers, contractors, and business executives is required. Salary to start \$50 per week plus 2 per cent commission. Address G. M. Duncomb, care of Dealers' Equipment Co., 3673 So. Michigan Ave., Chicago.

SALES ENGINEERS WANTED: One of the largest bearing manufacturers in America can use the services of two good sales engineers. Men with an engineering education and sales experience in farm tractor and implement field are preferred. They should have designing ability so that they can be of service to customers. Those experienced in the farm-implement and tractor design will be shown preference. Write fully giving all data as to experience, education and salary expected.